Comparative analysis between the industrial design product development methodologies (MPDI) together with an analysis of the scientific method (MC-14), an analysis based on Artificial Intelligence and Open Source programming (Python) of flowcharts (ISO 5807: 1985).

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Abstract

The five (5) stages of Design Thinking are analyzed, whose steps are: (1) empathize, (2) define, (3) ideate, (4) prototype and (5) test. Although it is to be assumed that in the development of the project, the development and design stages that every professional Industrial Designer and S&T Researcher must follow have been considered:

First: it is assumed that the industrial designer followed a "scientific method" of technological development (R+D+i) consisting of the following steps: (1) observation, (2) hypothesis, (3) experimentation, (4) measurement, (5) falsifiability, (6) reproducibility and repeatability (7) peer review, and (8) publication. In the contrast with (8) publication and its publication stages, the similarities and differences appear.

Second: Usually, in the (8) publication stage, the content of a scientific article for a journal will generally consist of the following headings (items): (a) title, (b)

abstract, (c) introduction, (d) materials and methodology, (e) results and discussion, (f) conclusion, (g) acknowledgments and (h) references. There is some flexibility in the labeling of these components, but they should be clearly identifiable and roughly in that order.
Third: Stages (1), (2), (3) and (4) of Design Thinking, mentioned above, make up items (d) materials and work methodology. Stage (5) of Design Thinking corresponds to item (e) results and discussion of the publication.
Fourth: So the scheme would be formed as follows:
(D) Materials and work methodology:
(1) Stage to empathize with users/clients (1) observation
(2) Definition stage
(3) Innovation ideation stage (2) design hypothesis
(4) Prototype manufacturing stage
(E) Results and discussion:
(5) Trial or testing stage (3) experimentation and (4) measurement
Conclusions (5) falsifiability of the design hypotheses.
If there are no design corrections, we proceed to (6) reproducibility (by other pairs of designers and engineers of the industrial manufacturing method of the product by means of plans and technical documentary material) and repeatability (or serial industrial production on an industrial scale of the manufacturing process). Industrial Design) (7) peer review (only affects the publication of the paper or article of the academic or scientific journal).

Keywords: Design Thinking, Design Methods, Scientific Research Methodology, R+D+i, ISBN/ISSN Publications.

Introduction to the debate.
This introduction does not claim to be absolutely true, but merely to challenge the reader and make him think about various questions of a diverse nature.
The problem of Industrial Design and the proliferation of design theories and methods is a major issue for analysis and debate when compared to the methodology of scientific research (which is not exactly the same, although it is something similar).
In short, design methods consist of creative design techniques to solve a design problem and arrive at a design solution (project: model, prototype).
However, scientific research methodology is the course that every doctoral student receives to write their doctoral thesis in Sciences (Exact, Natural, Social, etc.); it depends on the area of knowledge to which their academic discipline belongs (university degree or undergraduate degree held by the professional) and the Faculty that awarded it. There are academic debates as to whether Industrial Design should depend on a Faculty of Arts (as at the National University of La Plata - FBA-UNLP -, the National University of Misiones - FAYD-UNAM -, and the National University of Cuyo in Mendoza - UNCuyo -), a Faculty of Architecture (as at the University of Buenos Aires - FADU-UBA -, the National University of Córdoba - FAUD-UNC -, the National University of Mar del Plata - FAUD-UNMdP -, and the National University of San Juan - FAUD-UNSJ -), or if it should be related to Communication (as at the University of Palermo: Faculty of Design and Communication - UP); Just to cite a few

examples in Argentina, more closely related to Graphic Design, Textile Design, and other forms of audiovisual communication (including film, etc.). This also occurs in some instances in the Faculty of Fine Arts, where instead of adopting the name Graphic Design, it is called Design in Visual Communication (there are also other programs in audiovisual design and cinematography).

But the question regarding Industrial Design is: should it be a program dependent on an independent Faculty or dependent on a Faculty of Engineering? Because it's Industrial Design and is related to the industrial sector (Industrial Revolutions 1.0, 2.0, 3.0, and 4.0), SMEs, the metalworking industry, the automotive industry, the electronics and appliance industry, etc. It's completely removed from textile design, fashion, and catwalks. Right? The question is logical; its answer also involves logic and epistemological debate (doctoral studies), including a lot of philosophy of science.

At the beginning of the 21st century, Industrial Design finds itself immersed in a phase in which it is no longer possible to establish the predominance of one theory over the others. This is not serious in itself: the vast majority of disciplines are currently in a similar situation. However, in other related activities—such as architecture—the proliferation of theories, in the epistemological terms of Paul Feyerabend (1924-1994), emerges after centuries of consolidation of a specific theoretical system, embodied in treatises, academic formalization, and institutional activity. This prevails more in the Natural Sciences, Exact Sciences, and other highly formalized and standardized disciplines such as medicine.

This becomes even more difficult when the Social Sciences intervene, and it is possible to understand the current cultural and social crisis that has Industrial Design in an early stage of its theoretical consolidation in the face of postmodernism, which makes everything more complex, and Industry 4.0 (the fourth phase of the Industrial Revolution).

The crisis of Modernity is an unfinished discussion that has had different responses: that the modern project was never fully developed (Maldonado, 1993), that it went down the wrong path at a certain point, that it must move away from instrumental rationality, etc. In this sense, it is interesting to investigate the ways in which this discussion affects Industrial Design. In the cyclical scheme developed by Thomas Kuhn (1922-1996) of pre-science-normal science-crisis-scientific revolution-new normal science, it would be possible to affirm that architecture is currently in a state of crisis that aspires to reach a new normal science; meanwhile, Industrial Design appears to still be in a state of pre-science (mainly in Argentina, with an unconsolidated or undeveloped Third World industry like Brazil or the US). Despite the existence of precise heuristic, pedagogical, and technological procedures, sufficient conceptual density has not yet been achieved.

Isn't teaching industrial design a fraud to design students with a non-existent industry?

Obviously, students fall into the deception, believing in University Academies and a frankly decadent prestige that does not guarantee the job market for graduates (not mentioning this is ignoring the reality of the job market).

This reality is reflected in the shift towards teaching and research by professionals.

The first idea of this text is that the lack of definition of a theoretical framework for design is not necessarily negative but, on the contrary, can be positive.

Secondly, we will attempt to develop a brief description of some of the existing problems and establish where such a theory is nonexistent or precarious, yet increasingly necessary. To begin, we follow Feyerabend's ideas, which highlighted the advantages of multiple theories for explaining the same phenomenon, even if they are contradictory. Following the author, we can establish that the confrontation of theories can contribute to and enrich design theory over an extensive process.

In the search for different theories, each one must be solid and comprehensive in order to establish comparisons. Based on this conceptual development, we can discard those that do not demonstrate the expected characteristics of a theory: problem-solving power, heuristic capacity, social acceptance, and beauty.

Industrial Design has many fields to explore, and all require the construction of a theory that will allow it to establish solid foundations. We will examine some of these fields in the hope of constructing a possible research program, seeking an epistemological consolidation of the object of knowledge. The points developed below contain valuable research, professorial papers, and writings of varying levels and purposes obtained from various book authors and debates at Design Education and Teaching Conferences. There is no void, but rather the opposite: an immense proliferation of theories, many of them partial; some stemming from distant branches of knowledge; others from everyday practice. It is necessary to reformulate these fertile experiences into a comprehensive and coherent theoretical system. This is achieved without falling into the utopia of a comprehensive theory—a Newtonian paradigm that is possibly impossible to fulfill (as Tomás Maldonado intended)—but with research programs that go beyond pragmatism or casuistry.

The boundaries of Industrial Design have always been blurred, a circumstance that is now exacerbated. It's clear that any object produced by a machine can fall within the field of Industrial Design, but what happens when the answers to a problem involve the design of living beings? Biotechnology raises the possibility of designing life, on various scales. Design today can be applied not only to mechanical objects and artifacts, but also to living things. It might be dismissive to say that, by this criterion, everything could be an object of design and that biotechnology is a field of knowledge and work for geneticists and biologists. However, robotics—a science whose central focus is engineering—was a science in which designers had an influence: from the human-machine interface to the design of the functions that the robot in question had to fulfill, there is a portion of design knowledge that, at the time, exceeded what an engineer knew and gave rise to the participation of industrial designers. With the design of living beings, the process can be analogous: there is knowledge that exceeds that of a biologist and that could be complemented by an industrial designer.

Bionics has been designing objects for centuries (Leonardo Da Vinci) based on the solutions nature achieves for typical Industrial Design problems: how to better support oneself, optimize the use of materials, or store force. Should a field of Industrial Design dedicated to biology be opened, one that transcends bionics? What would be the conceptual framework for this field? What are its limits? So far, biotechnological designs have been microscopic (bacteria that eat accidentally spilled oil, plants resistant to certain herbicides, etc.).

Advances in nanotechnology are blurring the boundaries between the sciences of living organisms and the engineering of inanimate organisms. And here again, Industrial Design should provide a theoretical framework that goes beyond mere engineering utility. If the boundaries of Industrial Design are blurring toward life, this trend must be supported by a new scientific theory that includes ethical imperatives. Although difficult, it is not impossible, as other technical-political fields have shown in the past.
The problem of teaching Industrial Design. Most design faculties and schools around the world continue to apply a curriculum that has evolved little since the Bauhaus: workshop work, experiences with the perception of space and objects, an introductory course, and almost mystical characteristics of the creative process (hence its relationship with artistic creation and the creativity of the "creative genius"). However, three aspects have changed significantly since the Bauhaus: the emerging digital paradigm and its influence on the way we represent and think about reality; the challenge of the overabundance of information (the Internet) and the difficulty of filtering through the data relevant to our work; and the need to provide massive, high-quality education at universities.
In the first of the fields mentioned, a theory that systematizes contributions from different areas and provides answers to problems that have no solution is essential: returning to Kuhn's scheme, the need to provide answers to problems that old theories do not resolve is one of the central points in the paradigm shift.
The reference is about Thomas Kuhn (1922-1996) and his important theoretical work*The structure of scientific revolutions (1962) and what the author considered a paradigm.*
The philosopher and scientist Thomas Kuhn gave paradigm its contemporary meaning when he adopted it to refer to the set of practices that define a scientific discipline during a specific period. These include: the kinds of questions that are supposed to be asked to find answers to the objective; how those questions should be structured; how the results of scientific research should be interpreted. To paraphrase the author, the paradigm's success is sufficiently unprecedented to attract a lasting group of supporters, drawing them away from the competitive aspects of scientific activity, and sufficiently incomplete to leave many problems to be solved by the redefined group of scientists.
Before the first universally accepted paradigm, there may be multiple paradigms coexisting even if they are mutually exclusive.
Likewise, the new paradigm implies a new and more rigid definition of the field. Those unwilling or unable to adjust their work to the field must continue in isolation or join some other group. Paradigms gain their status because they are more successful than their competitors in solving a few problems that the group of professionals has come to recognize as acute. However, being more successful does not mean that they are completely successful in solving a given problem or that they produce sufficiently satisfactory results with a considerable number of problems.
An example of a paradigm is Newton's classical physics and Einstein's physics.
In the same way, we could say that artisanal design forms a stage of the pre-industrial phase (analogous to Kuhn's "pre-scientific" stage) and the industrial phase - after the first English Industrial Revolution - corresponds to Kuhn's "normal science" stage; when the anomalies that introduce the new paradigm

begin to appear (just as Albert Einstein and his Theory of Relativity did with classical Newtonian physics); Postmodernism and the incipiently anomalous aspects that were mixed with the aspects of Industry 4.0 - climate change, new energy sources, ecodesign, etc. - are making

Phase 1: “pre-scientific”	Phase 1: pre-industrial (artisanal)
Acceptance of a paradigm	Acceptance of the artisan paradigm
Phase 2: “normal science”	Phase 2: “normal science”
Appearance of anomalies	Appearance of anomalies
New paradigm	New industrial paradigm
Phase 3: Revolutionary Science.	Phase 3: 1st Industrial Revolution

Table 1: Kuhn's analogy chart between the three phases of science (pre-scientific, normal science, and revolutionary science), on the left; and a correlation with the First Industrial Revolution in England in the late 18th and early 19th centuries. Source: Prepared by the authors.

Phase 1: pre-industrial (artisanal)
Acceptance of the artisan paradigm
Phase 2: “normal science”
Appearance of anomalies
New industrial paradigm
Phase 3: 1st Industrial Revolution (Industry 1.0)
Emergence of environmental anomalies due to industrial effects (industrial pollution, oil spills, smog, acid rain, increasing carbon footprint, global warming, presence of heavy metals in water, various toxic chemical effluents into the air, soil and water, desertification, salinization, etc.).
New industrial paradigms: ecodesign, alternative energy sources (solar, wind, hydrogen, etc.), robotics, artificial intelligence, blockchain, nanotechnology, biotechnology, Internet of Things, 3D printing, autonomous vehicles, cyber-physical systems, Internet of Things, cloud computing.
Phase 4: Industry 4.0

Table 2: Analogy chart of the evolution of the “industrial paradigm” of Industry 1.0 and the emergence of anomalies that lead to the crisis of this paradigm and the emergence of a “new paradigm” or “Industry 4.0 paradigm” (to which today's Industrial Designer must adapt if they want to survive the changes). Source: Prepared by the authors.

Digital tools began as a way to aid representation, but they now imply a different way of thinking about the objects being designed. If what traditional cognitive theories of the hand-brain relationship hold true, what was previously resolved in freehand sketches—and which exchanged data back and forth to the black box of creativity—is now done by computers, which should change theories about the design of new objects, how we think, and how we teach thinking and design.
The second problem has to do with the amount of information available to students from the Internet. Without any filter, it's difficult to recognize its quality, because the legitimization mechanisms that used to consist of peer committees that selected works for publication have also been lost—in design, this has

never been as clear as in other disciplines. The only legitimization of Industrial Design seems to come from design magazines, an integral part of the commercial apparatus that makes us look at and discuss Starck's frivolous citrus juicer more than Papanek's participatory experiences.

The third area is something we experience daily in our Latin American faculties and schools, which are often structured around massive courses, with lax or non-existent entrance exams and few teachers, frequently poorly paid and with little incentive (who are unfamiliar with the private market and do not work, and therefore do not really know: why do they teach?).

Returning to the Bauhaus (the old paradigm of Industry 1.0 and obsolete Modernity), that experience emerged from a debate in early 20th-century Germany that encompassed teaching in schools, the relationship between design and production, the need to add design value to national industry, and the value of education as an inclusive element.

As a way of building citizenship from design, a new theory of teaching this discipline must consider mechanisms to ensure widespread and quality education in Argentina. The relationship with businesses should also be reconsidered, a taboo subject, either due to ideology or due to the ineffectiveness of both parties (university/business) in addressing it (perhaps private universities are more advanced on this topic because they lack ideological issues with the labor market and what the Argentine National Constitution itself promotes: Capitalism). This is what the Founding Fathers thought, and this author defends it (he defends the need for industry, private property, and industrial capitalism).

Shouldn't we also consider creating technical schools, secondary schools, and institutions—not just universities—that would improve the quality or taste of lower-capacity productive sectors, from crafts to SMEs?

In more progressive circles, Industrial Design seems to be considered—and rightly so, in light of current experience—little more than a discipline legitimizing capitalism that, through formalist tools like styling or propaganda tools like branding, intervenes in marketing strategy. In this sense, it is interesting to analyze the relationship between the rise of capitalism and Industrial Design. Was this design always at the exclusive service of capitalism? Did it never resolve the contradiction suffered by Williams Morris, who aspired to a quality yet mass-market design?

It's clear that there can be no Industrial Design without industry, and that this emerged after the Industrial Revolution, a crucial moment in which the process that commodifies everything takes place: labor, land, time, and even money. If everything is a commodity, the only thing Industrial Design can do is add value to products to conquer markets. These questions suggest a few: Is the relationship between Industrial Design and capitalism inevitable, univocal, and subservient? Is it true that Industrial Design must always tend toward planned obsolescence or conspicuous consumption?

In short, a theory is needed that answers the following question: can there be industrial production, and therefore Industrial Design, in a non-consumerist society? Can innovation exist without the spur of constant change? During World War II, theoretical, political, and legislative efforts were made to "naturalize" the concept of a self-regulating market, and all that it entails, including the idea that the goal of Industrial Design, like everything else, is to sell more.

Selling more (or less) implies producing, and producing implies a method or a methodology.

Development

The project*"Integrated Design and Innovation Management. Contributions to a Theoretical-Conceptual and Methodological Review" (Code 11/B374), led by Director Federico Del Giorgio Solfa. The project's dates (according to SCyT-FBA-UNLP): January 1, 2020, to December 31, 2021. This project responds to the need to survey, analyze, and establish a database of new theories, concepts, categories, and definitions related to design and innovation management, focusing on three main areas: marketing, local development, and entrepreneurship. These areas will be transversally analyzed through the following approaches: education, profession, and research. The main contribution is a comprehensive thematic development, reviewing theories and authors, analyzing concepts and categories, and reinterpreting their definitions using representative models and cases from the repertoire and heritage of industrial designers trained at universities.*

In this brief analysis we will focus on a critique of the methodology of the*Design Thinking, flaws found when applied to a case of Industrial Design development in education (Technical School No. 2 "Independencia", Concordia, Entre Ríos). The flaws found in Design Thinking, as a method applied to the design of the "Energy-efficient centrifugal extractor for COVID-19 contaminated air. PMSM/IPM type synchronous motor, single-phase alternating current 220 (V) and 50 (Hz), high energy efficiency (EE), for use in centrifugal extractors and/or blowers applied to SARS-CoV-2 (Coronavirus) ventilation." Text prepared for the UIS-Ingeniería de Colombia journal and for the IDTS electronic journal of the UNLP.*

The prototype was developed following the five (5) stages of Design Thinking, which was initially popularized by the Silicon Valley firm IDEO, and whose steps are: (1) empathize, (2) define, (3) ideate, (4) prototype and (5) test.

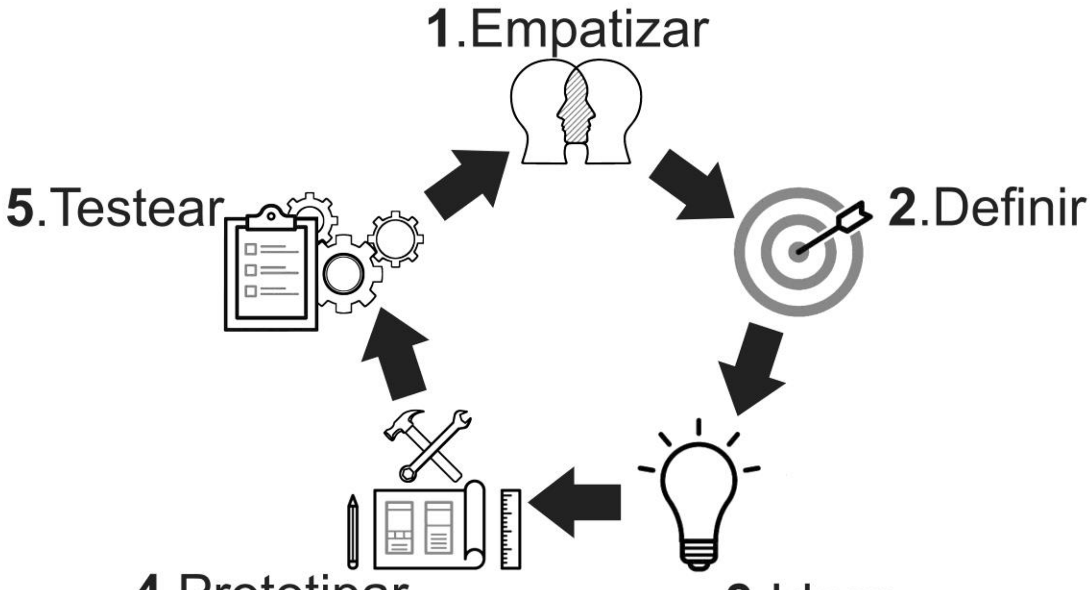

Figure 1. Stages of Design Thinking.

The designed product is a centrifugal air extractor/blower, which solves the problem of environments contaminated by SARS-CoV-2 or Covid-19 (Coronavirus), designed for civil and commercial use, it works with a 220 (V) and 50 (Hz) single-phase alternating current (AC) motor, with high energy efficiency (EE). Developed under the Design Thinking methodology, by electromechanical simulation using NI Multisim 14.0 software, housing design by CAD using Cfturbo 2020 R2.0 software plus free software and rapid 3D prototyping with the OverLord Pro 3D printer provided by INET (National Institute of Technological Education); with a prototype of the conventional stator winding of a synchronous motor with a two-pole PMSM/IPM type single-phase alternating current (AC) field winding and a 4000 (Gauss) ferromagnetic ceramic magnet rotor.*Innovating on line no. 15 of Nikola Tesla's invention patent no. 381,968, 1/5/1888.*

One of the objectives is to link the secondary or technical school level with the university system (and with careers with a technological profile) through Project B374. Links were also sought with the Research and Development Laboratory of the Department of Industrial Design (LIDDI-FBA-UNLP) through its Director, DI Pablo Ungaro, and with the Technological Liaison Unit of the National Technological University (UVT-UTN), Concordia region (Entre Ríos), through Mr. Martin Azzali.*creating development ties so that future students graduating from secondary level (Secondary - Technical) value the usefulness of knowledge with technological profiles such as Industrial Design, Engineering and Research plus Technological Development and Innovation (R&D&I), as described in the new Law of the Knowledge Economy (Law No. 27,570).*

In 2021, the project participated in the INNOVAR National Competition of the Ministry of Science, Technology and Productive Innovation of the Nation (MINCYT), in the category*Secondary schools or technical schools (Law 26.206, Art. 17), having been selected in the catalog of innovative products and having obtained the First Prize in the COVID-19 Innovate category.*

According to preliminary findings, analysed on the test bench, the PMSM/IPM type synchronous motor used in the centrifugal extractor, with the innovation of series inductive reactance control plus parallel capacitor, reduces active power (Watts) and active energy consumption (kWh) by 67%, performing 56% more mechanical work (Joules) on the air fluid (with a 50% reduction in the carbon footprint).*Which leads us to another statement: centrifugal fans can be developed that save electricity (kWh) without resorting to: (a) the "Fan Affinity Law" or (b) the use of variable speed drives (VFDs) or frequency drives (which are devices with complex and expensive electronics). This would result in enormous savings in electricity costs for domestic, commercial, and industrial ventilation. This technology is simple, albeit rudimentary and limited; but effective, economical, and simple (electromechanical, not electronic), which, according to empirical evidence and experimental tests, has been shown to effectively work.*

With less technology, the electromechanical design was simplified, reducing costs and achieving economic savings in energy expenditure (kWh).

This work was written and presented independently for the CUADERNOS magazine of the National University of Palermo.

The project development has been considered in the development and design stages.
*First:*It is assumed that the industrial designer followed a “scientific method” of technological development (R&D&I) consisting of the following steps: (1) observation, (2) hypothesis, (3) experimentation, (4) measurement, (5) falsifiability, (6) reproducibility and repeatability (7) peer review and (8) publication. The similarities and differences appear in contrast to (8) publication and its publication stages.
*Second:*Typically, at the (8) publication stage, the content of a scientific article for a journal will generally consist of the following headings (items): (a) title, (b) abstract, (c) introduction, (d) materials and methodology, (e) results and discussion, (f) conclusion, (g) acknowledgments, and (h) references. There is some flexibility in the labeling of these components, but they should be clearly identifiable and should follow roughly that order.
*Third:*The aforementioned stages (1), (2), (3) and (4) of Design Thinking comprise items (d) materials and work methodology. Stage (5) of Design Thinking corresponds to item (e) results and discussion of the publication.
*Room:*So the scheme would be formed as follows:
(D) Materials and work methodology:
(1) Stage to empathize with users/clients (1) observation
(2) Definition stage
(3) Innovation ideation stage (2) Design hypothesis
(4) Prototype manufacturing stage
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If there are no design corrections, we proceed to (6) reproducibility (by other pairs of designers and engineers of the industrial manufacturing method of the product through plans and technical documentary material) and repeatability (or industrial production in series on an industrial scale of the Industrial Design process) (7) peer review (only affects the publication of the "paper" or article in the academic or scientific journal).

Materials and methodology

The state of the art (State of the Art) refers to the most significant theoretical frameworks or bibliographical compilation on the following design design methods. For example, the bibliography on: (a) Bruno Munari's design methodology, (b) Victor Papanek's integrated generalizing design, (c) Christopher Jones's input-output relationship, (d) Bernd Löbach's creative problem-solving process, (e) Abraham Moles' taxonomic methodology, (f) Gui Bonsiepe's design methodology, (g) Jordi Llovet's textual/contextual method, (h) Oscar Olea and Carlos Gonzales Lobo's Diana model, (i) UAM Azcapotzalco's general design process model. And other authors.
Below we will illustrate only nine (9) selected models, among the best known or representative for their graphic representation of the method: (1)Bruno Munari, (2) Victor Papanek, (3) Christopher Jones, (4) Bernd Löbach, (5) Tom Dixon, (6) Harley J. Earl, (7) Ing. Edward Krick, (8) MorrisAsimow and (9) BruceArcher. That is, because they can be represented or schematized visually without

further theoretical development, and are easily understood by those familiar with Industrial Design projects and their various stages.
The development of the following nine (9) selected models does not in any way imply that one is better than the other. Rather, they are somehow representative due to their graphic and visual significance (ability to be visually summarized for schematic interpretation).

(1) Project method: Bruno Munari
The design method (see figure 1) simply consists of a series of necessary operations, arranged in a logical order dictated by experience. Its purpose is to achieve maximum results with minimum effort.

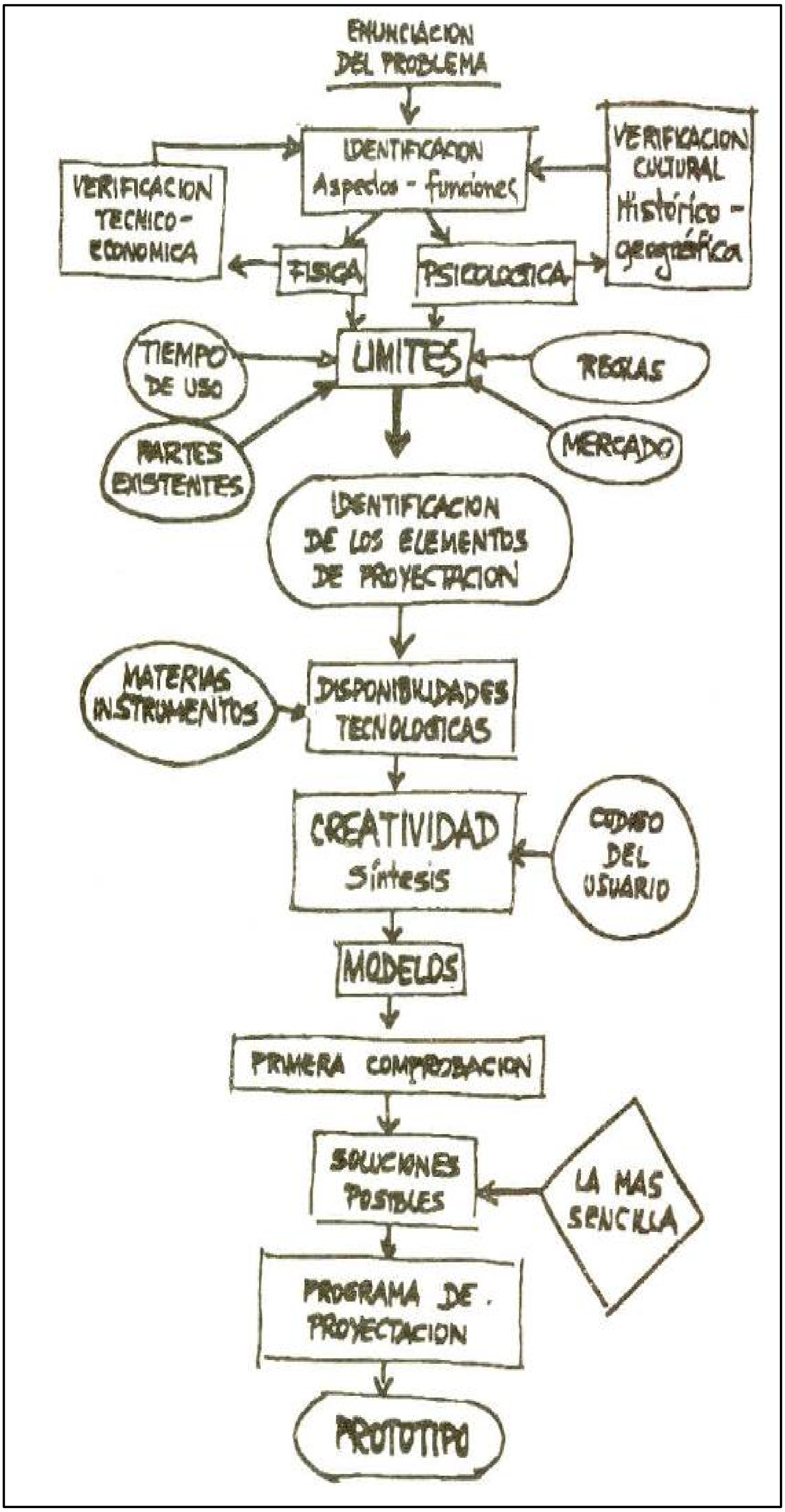

Figure 2. Munari model

Here are the 10 steps listed and briefly explained for industrial design, based on Bruno Munari's method:

Problem Definition: Fully understand the challenge you need to solve. Clearly define the problem and listen to the customer.
Idea: Develop an idea that will lead you to the solution. Consider whether you need a cost-effective, temporary, or permanent solution.
Creativity: Examine each part of the problem and look for imaginative solutions.
Complex Analysis: Distinguish between what is complicated and what is complex. Analyze the parts of the problem and group them together.
Experimentation: Test your ideas and verify their viability.
User Research: Understand the needs and desires of users.
Prototyping: Create physical or digital prototypes to test your ideas.
Iteration: Continually improve the design based on feedback and results.
Feasibility Assessment: Considers technical, economic and environmental viability.
Documentation: Records the entire design process, from sketches to manufacturing details.

(2) Integrated generalizing design: Victor Papanek
Victor Papanek's method (see figure 2) derives from pedagogy and insists on interdisciplinary teams in which related specialties allow the designer to broaden the spectrum of creative innovative penetration.

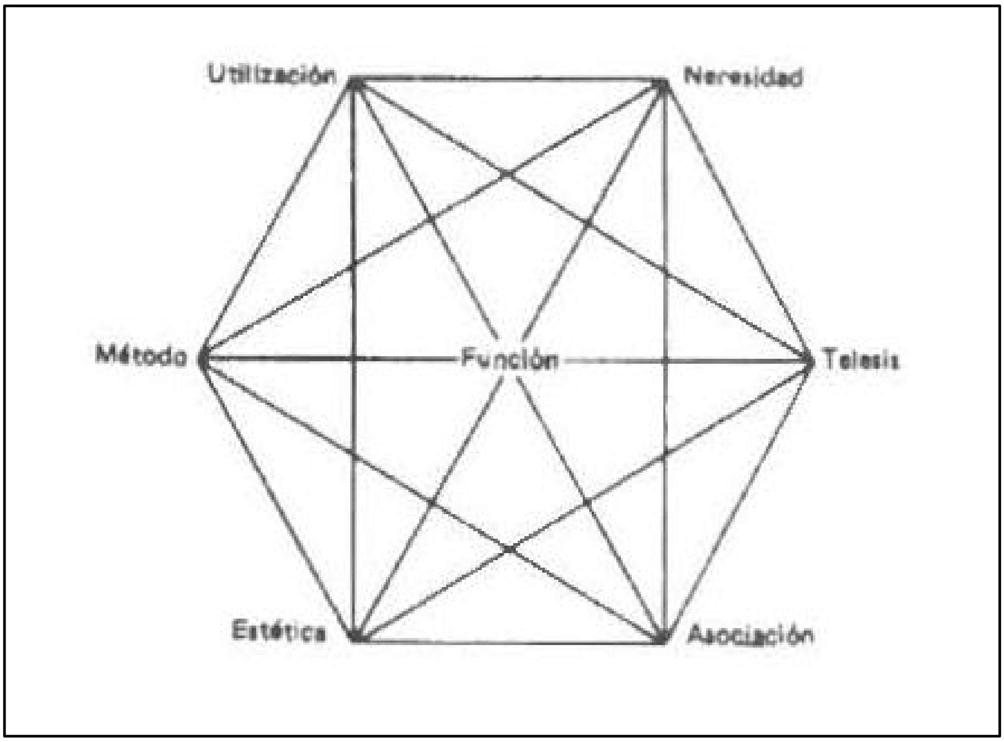

Figure 3. Papanek model

Method:
It involves the optimal use of processes, tools and materials.
Consider efficiency, cost and environmental consequences.

Prevents the material from appearing to be something other than what it is.
Use:
It refers to the main application of the product and its specific characteristics.
Consider how the design should properly fulfill its function.
Need:
Analyze the environment to detect real needs and possible improvements.
Seek to satisfy vital needs, not whims or trends.
Telesis:
Design according to the context and social and economic conditions.
Reflect the times and conform to the general human order.
Association:
Consider the relationship between people and designed objects.
Explore adaptations and "second uses" that users make.
Aesthetics:
It's not just about the visual, but about how design affects society.
Seek relevant and sustainable social impact.

(3) Inputs-outputs: Christopher Jones
Christopher Jones's method (see Figures 3 and 4) considers the designer to develop a chain of interrelated specifications and predictions to formulate proposals that respond to given requirements. The method is the means to resolve the conflict between rational analysis and creative thinking.

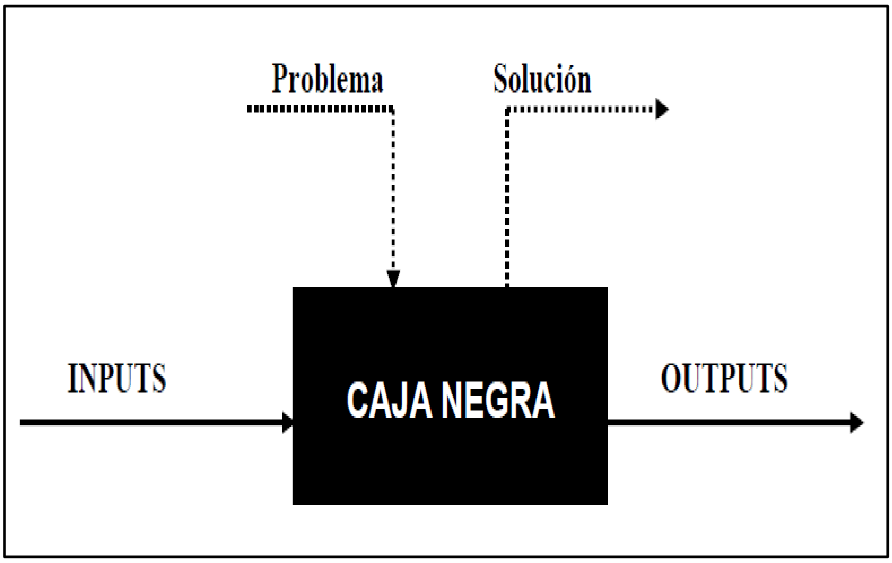

Figure 4. Jones model

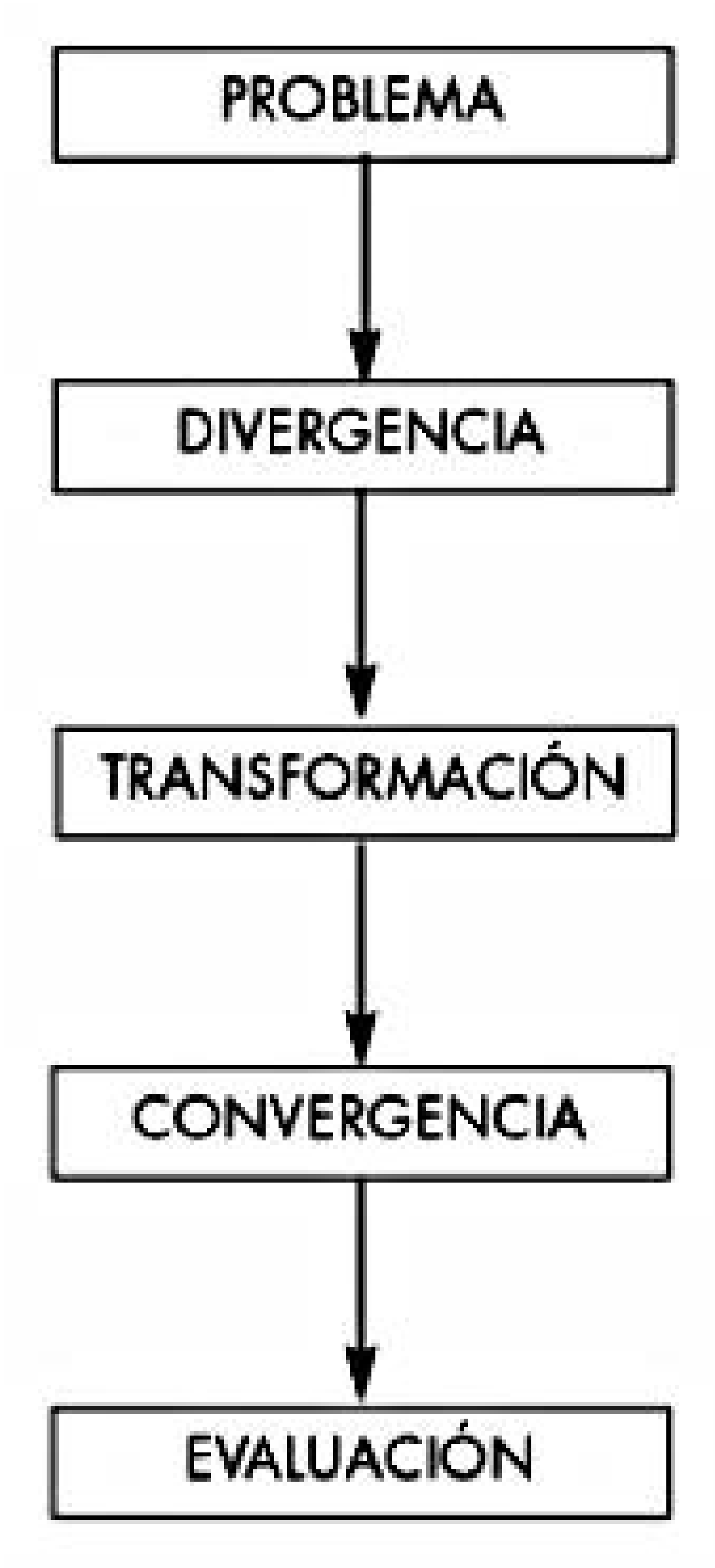

Figure 5. Sequence of Christopher Jones's "Transparent Box" process.
The black box methodology proposed by Christopher Jones is an interesting approach to design. Although he did not develop a specific method, his ideas have influenced the common language of design. Here are the key aspects of this methodology:

Imagination: Start by imagining possible solutions.

Intuition and Reason: Combine both approaches to solve problems.
Context: Design considering the environment and social conditions.
Modeling: Evaluate the contextual effects of what you imagine.
Adaptability: Adjust the process according to what is happening.
Rejection: Discard what does not contribute or diminishes.

(4) Creative problem-solving process: Bernd Löbach

Bernd Löbach's method (see figure 5) considers the design process as the set of possible relationships between the designer and the designed object so that it becomes a technologically reproducible product.
The number of possible combinations and the probability of different solutions are derived from the multidimensional approach.
Bernd Löbach, an industrial designer and design theorist, proposed a methodology that combines creativity and problem-solving in the design process. Although he did not develop a specific method called the "Creative Problem-Solving Process," his ideas have influenced the field of design. Here are the key aspects of his approach:

Preparation Phase:
Problem Analysis: The designer acquires a thorough understanding of the problem. Relevant information is gathered, the problem is classified, and the objective is defined.
Need and Social Relationship: Consider how many people are interested in solving the problem and evaluate the connection between the user and the designed object.
Incubation Phase:
During this stage, the designer processes the information gathered and allows ideas to mature subconsciously.
Creativity and exploration of multiple approaches are encouraged.
Solution Phase:
Solutions are developed for the identified problem.
Solutions are evaluated according to established criteria (efficiency, feasibility, social impact, etc.).
The most appropriate solution is selected and implemented.

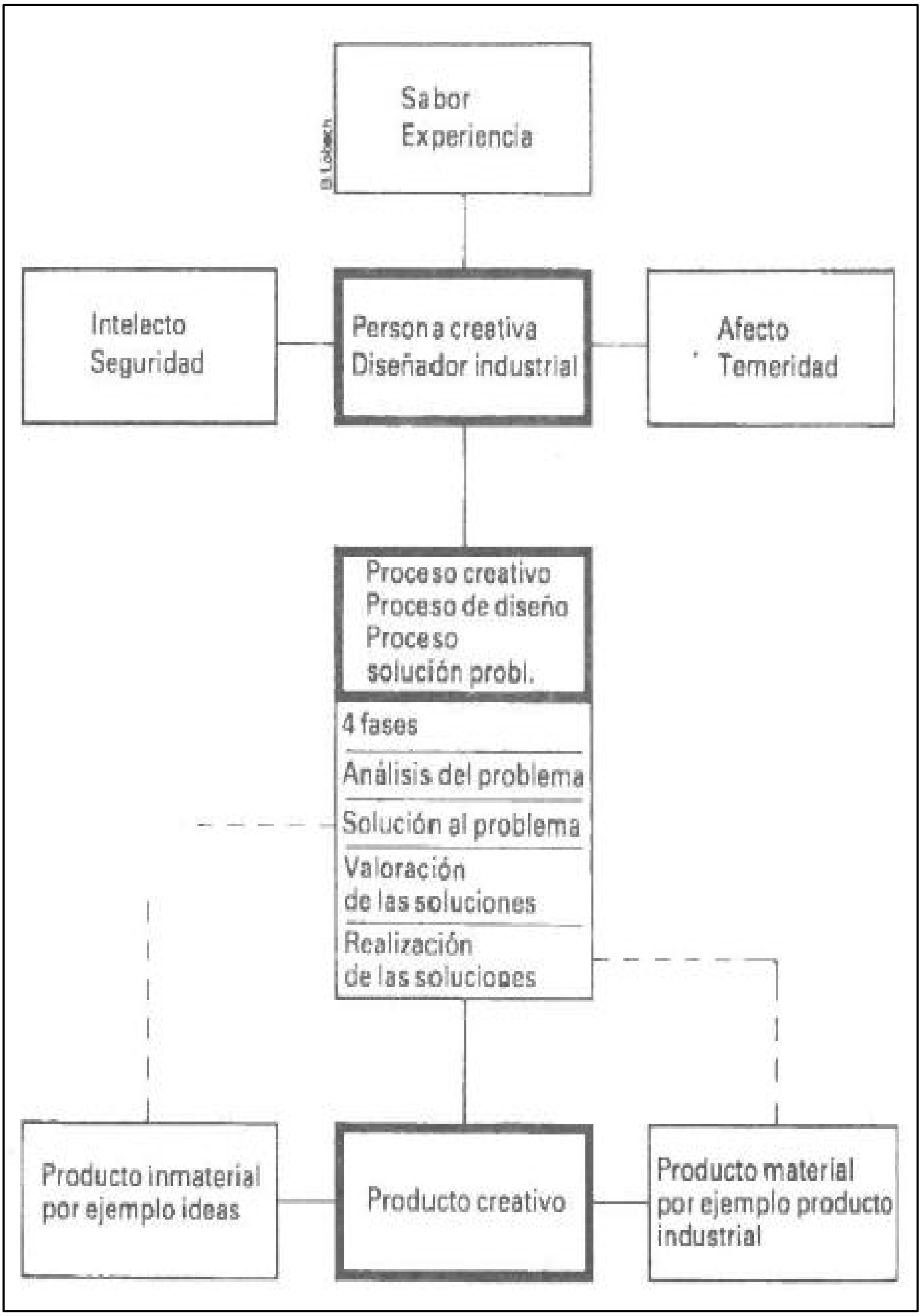

Figure 6. Löbach model

(5) Dixon design method

Dixon's method (see Figure 6) considers the first step to recognize and understand the goal or objective, which may have been assigned or may be a self-imposed goal. Once the idea to solve the problem has been found and selected (which entails another decision), the engineer must analyze it. Once the analysis is complete, if the results are favorable, the engineer must translate his or her solution into production terms.

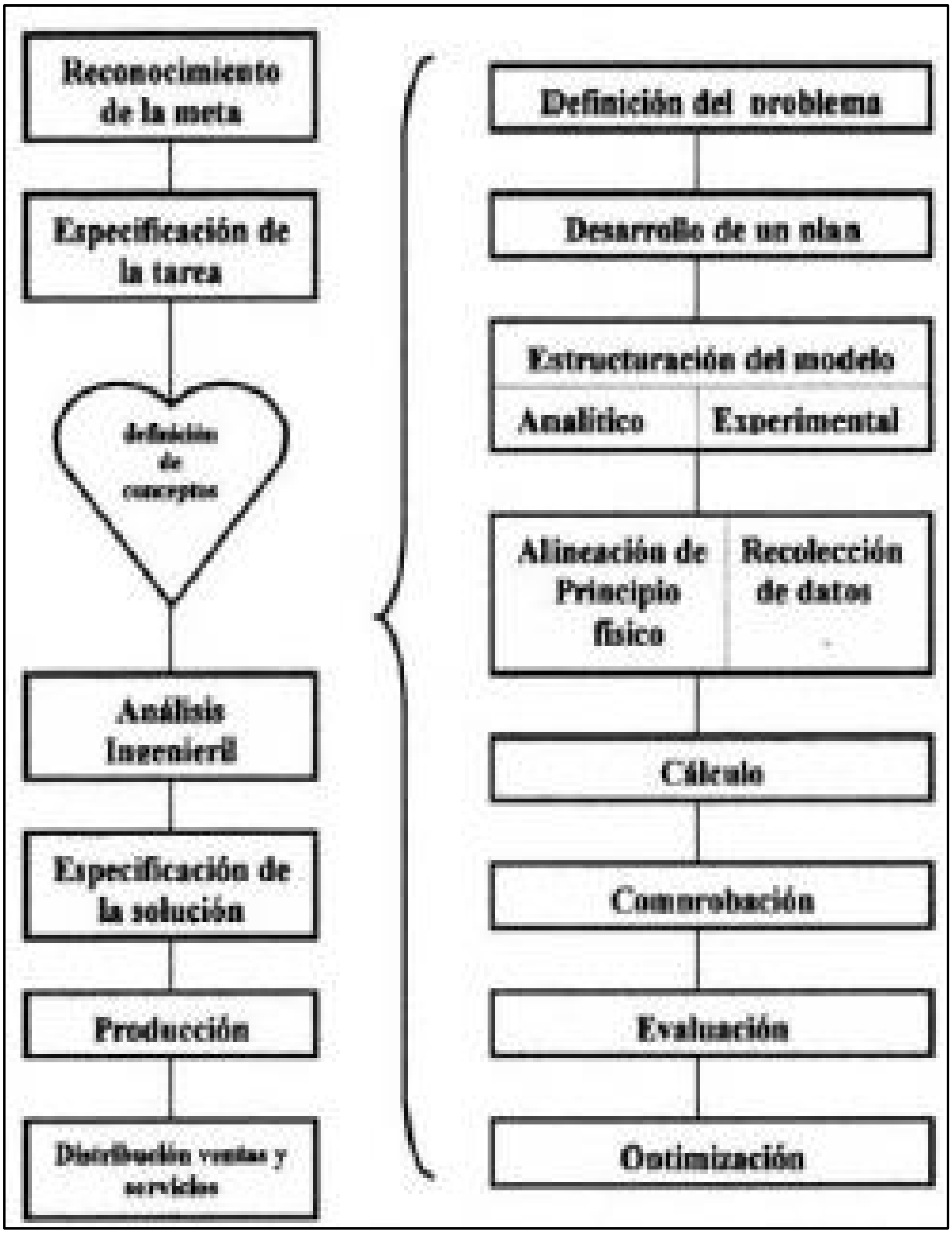

Figure 7. Dixon model

Recognition and Understanding of the Goal or Objective:
Clearly identify the goal or objective of the process. It can be an assigned goal or one you set yourself.
Selecting the Idea to Solve the Problem:
Find and select the idea that you think will solve the problem.
Analysis of the Idea:
Evaluate the idea in terms of feasibility, efficiency and effectiveness.
Transcription of the Solution in Production Terms:
If the results are favorable, document the solution clearly and concisely.

You can use tools like Lucidchart to create your flowchart1.

(6) Earle design method
In Earle's method (see figure 7), some basic stages are considered in the design process for application in engineering problems.

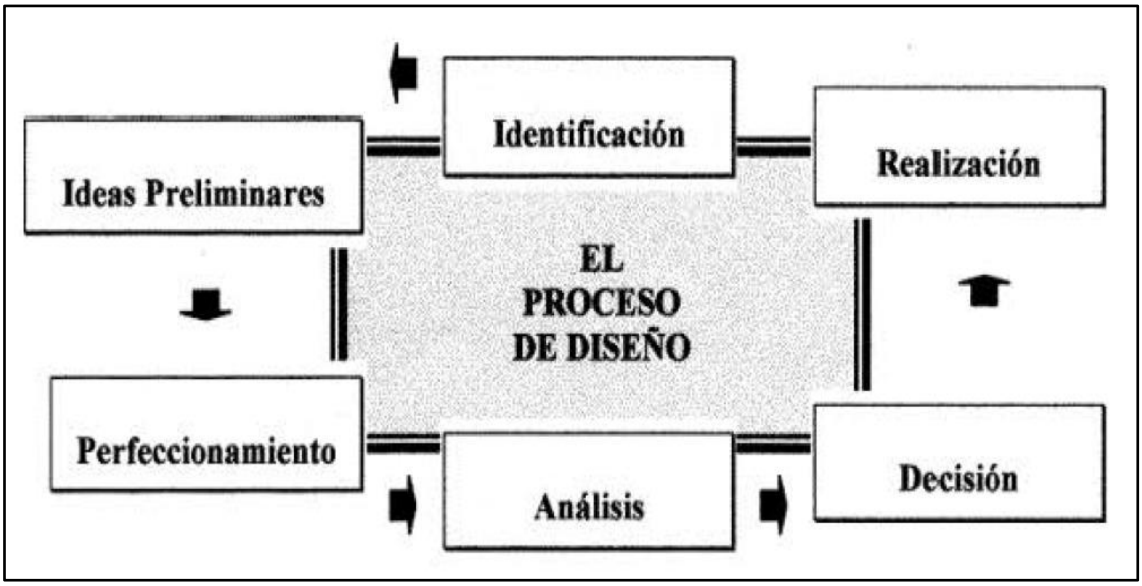

Figure 8. Earle model

(7) Krick design method
In the Krick method (see figure 8), the steps that the design process should contain are considered to be: problem formulation, problem analysis, search for possible solutions, decision and specification.

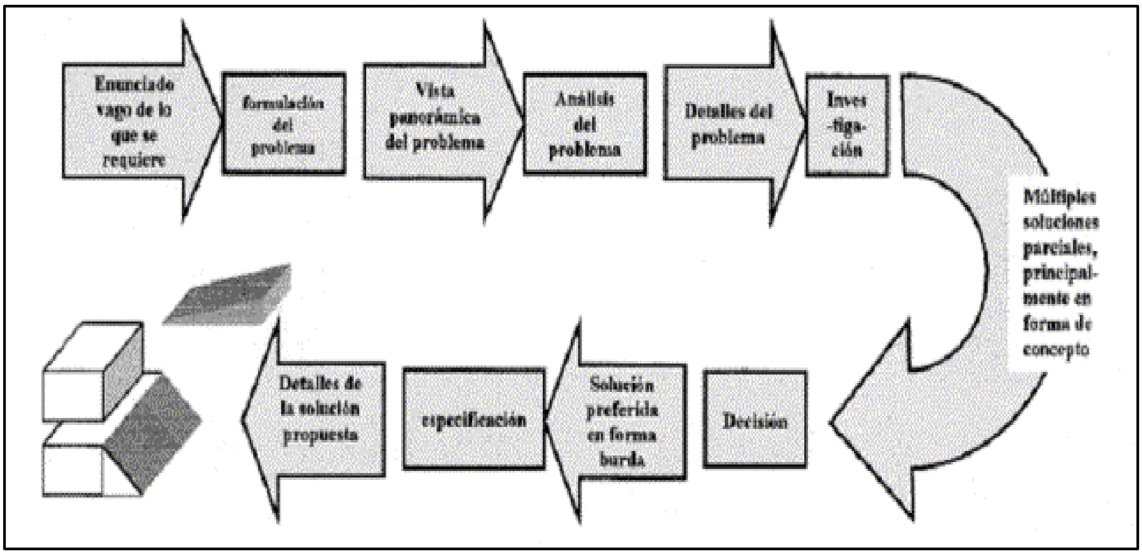

Figure 9. Krick model

Problem Statement:
Take the initial time to define the problem briefly and without going into too much detail.
Avoid thinking prematurely about improvements or the current solution.
Don't over-describe the current method.

Problem Analysis:
Focus on discovering and analyzing the problem's constraints.
Consider only real and valid restrictions.
Try to determine which aspects are modifiable.
Search for Possible Solutions:
Search for various alternatives using specific criteria and the volume of possibilities.
Encourages inventiveness and applies principles of better working methods.
Evaluation and Selection:
Evaluate alternatives after the search, not during.
It considers both required times and intangible criteria.
Bases total labor costs on long-term productivity.
Specification:
Adequately describe the selected method and its execution characteristics.
Use communication media, such as auxiliary instructions, to complement the standard description of the method.
Surveillance and Design Cycle:
Oversees the implementation of the method and its use to complete the design cycle.

(8) Asimow design method

Asimow's method (see figures 9 and 10) considers two major phases that are interrelated. Morris Asimow, in his most widely published work, describes the entire design process and is a clear example of how industrial designers have turned their attention to engineering methods.

Planning and Morphology Phase:
Feasibility Study: Evaluates the viability of the project.
Preliminary Design: Generates initial ideas and concepts.
Detailed Design: Defines the components and subsystems.
Production Process Planning: Prepares for manufacturing.
Distribution Planning: Organizes the physical layout.
Consumption Planning: Consider the use of the product.
Product Retirement Planning: Plan your product life cycle.
Detailed Design Phase:
Design Preparation: Document the chosen solution.
Total Subsystem Design: Integrates the components.
Total Component Design: Details each part.
Detailed Design of Parts: Defines specifications.
Preparing Assembly Drawings: Create plans.
Experimental Construction: Prototype and test.
Product Testing Program: Evaluate its performance.
Analysis and Prediction and Redesign: Refine based on results.
Design Process Summary:
Analysis, Synthesis, Evaluation and Decision, Optimization, Review and Implementation.

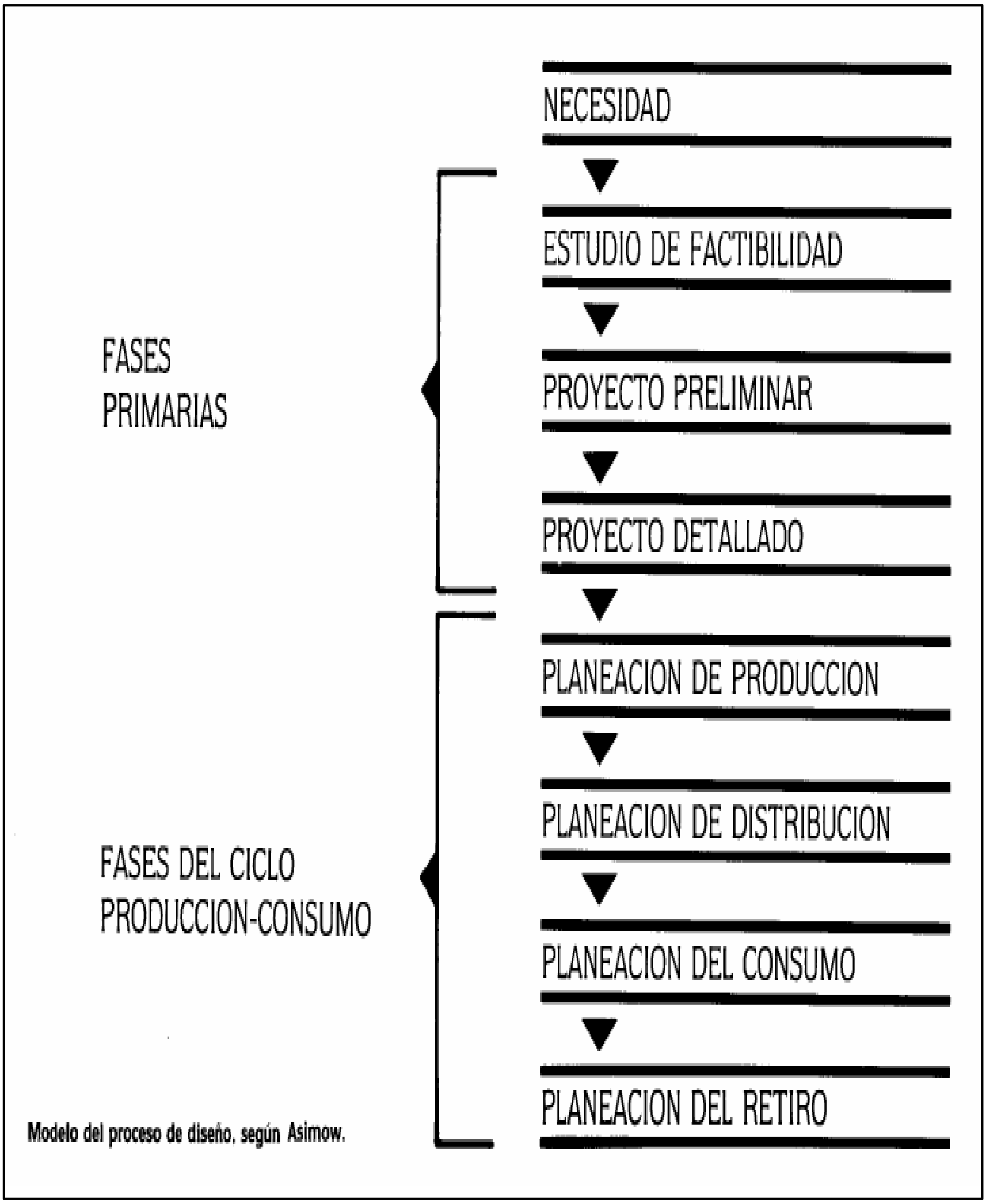

Figure 10. Asimow model

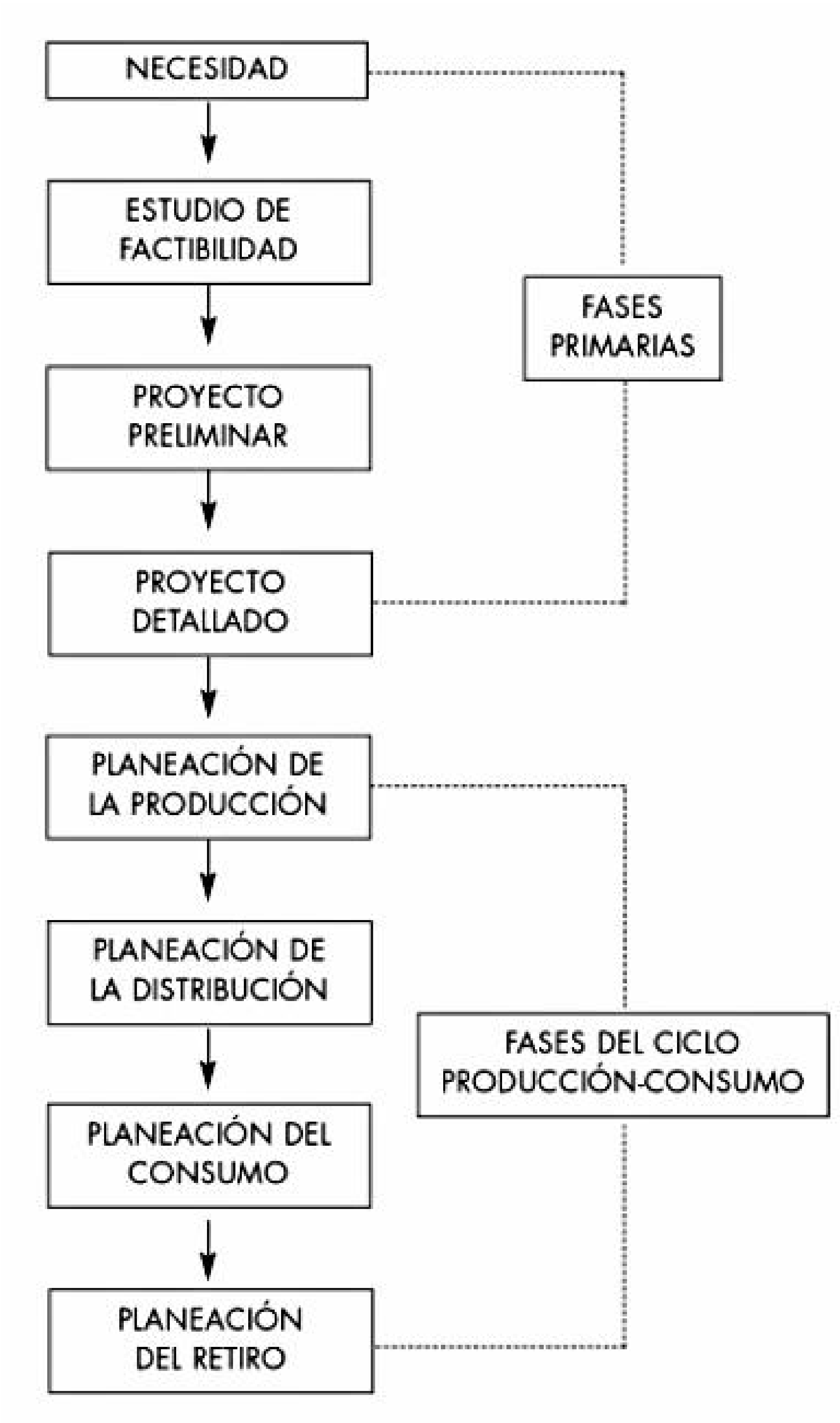

Figure 11. Sequence of the design process according to Morris Asimow.

(9) Archer's design method
Archer's method (see figures 11 and 12) considers that the design process should fundamentally contain the analytical, creative and execution stages.

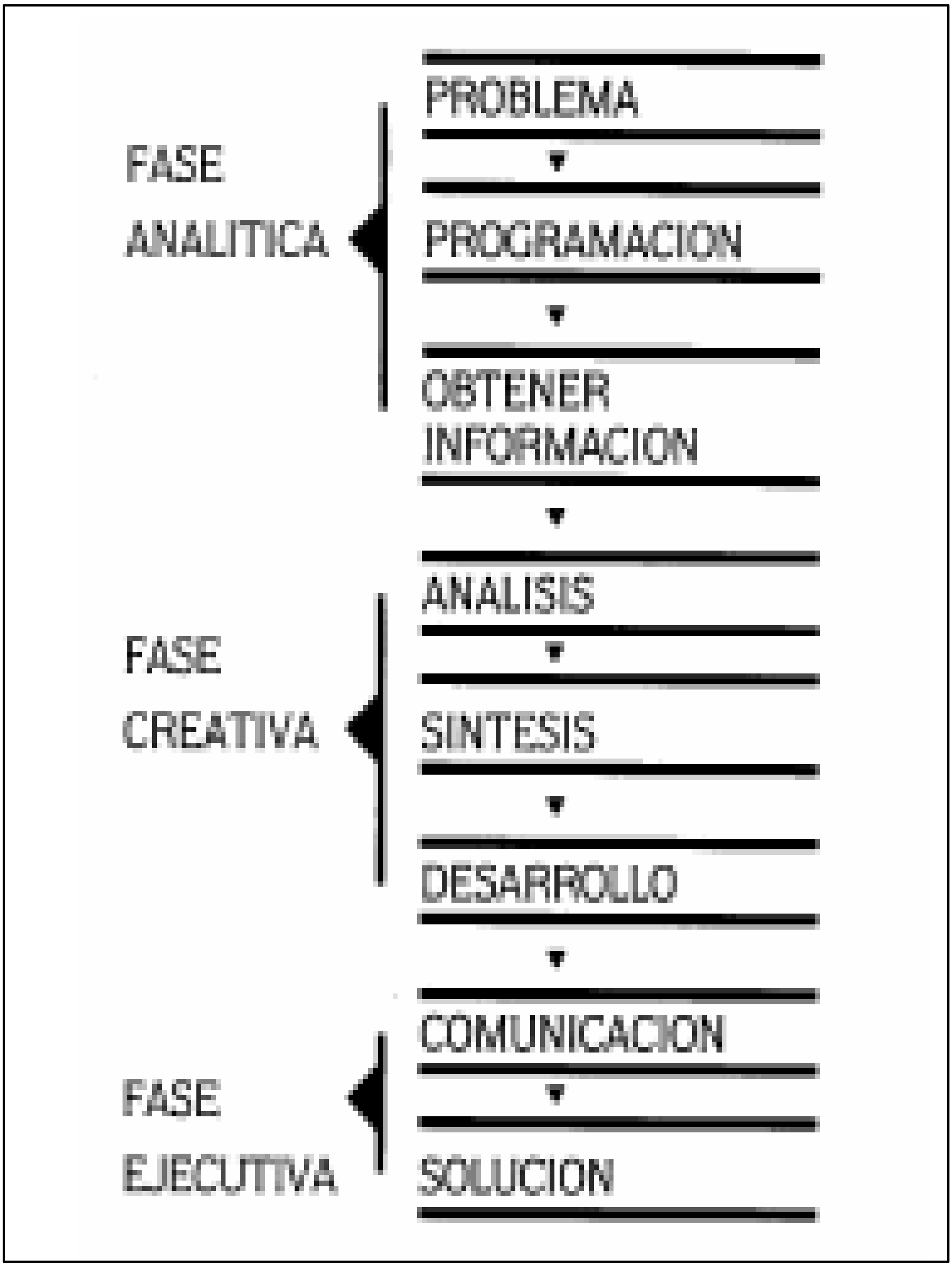

Figure 12. Archer model

Problem Definition and Preparation of the Detailed Program:
Start by clearly defining the problem and preparing a detailed program.
Identify design needs and constraints.
Obtaining Relevant Data and Preparing Specifications:

Collect relevant data and develop specifications.
Feed back to the problem definition phase with this information.
Data Analysis and Synthesis for Design Proposals:
Analyze collected data and synthesize design proposals.
Considers functional, aesthetic and production aspects.
Prototype Development:
Create prototypes to validate design proposals.
Make adjustments based on the results obtained.
Studies and Experiments to Validate the Design:
Conduct studies and experiments that support the viability of the design.
Evaluate your performance and adjust if necessary.
Preparation of Documents for Production:
Document the final solution clearly and concisely.
Prepare the necessary documents for manufacturing.

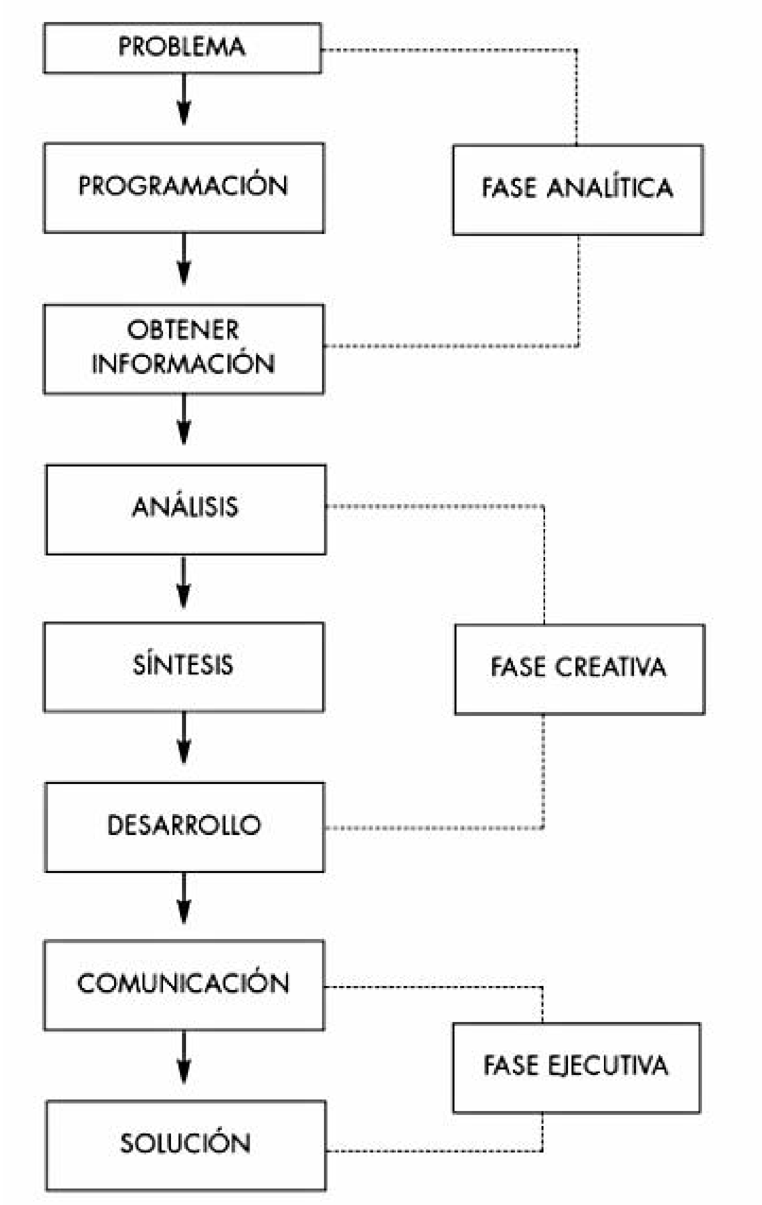

Figure 13. Archer's design process model.

(11) Hans Gugelot method.
See figure 13.

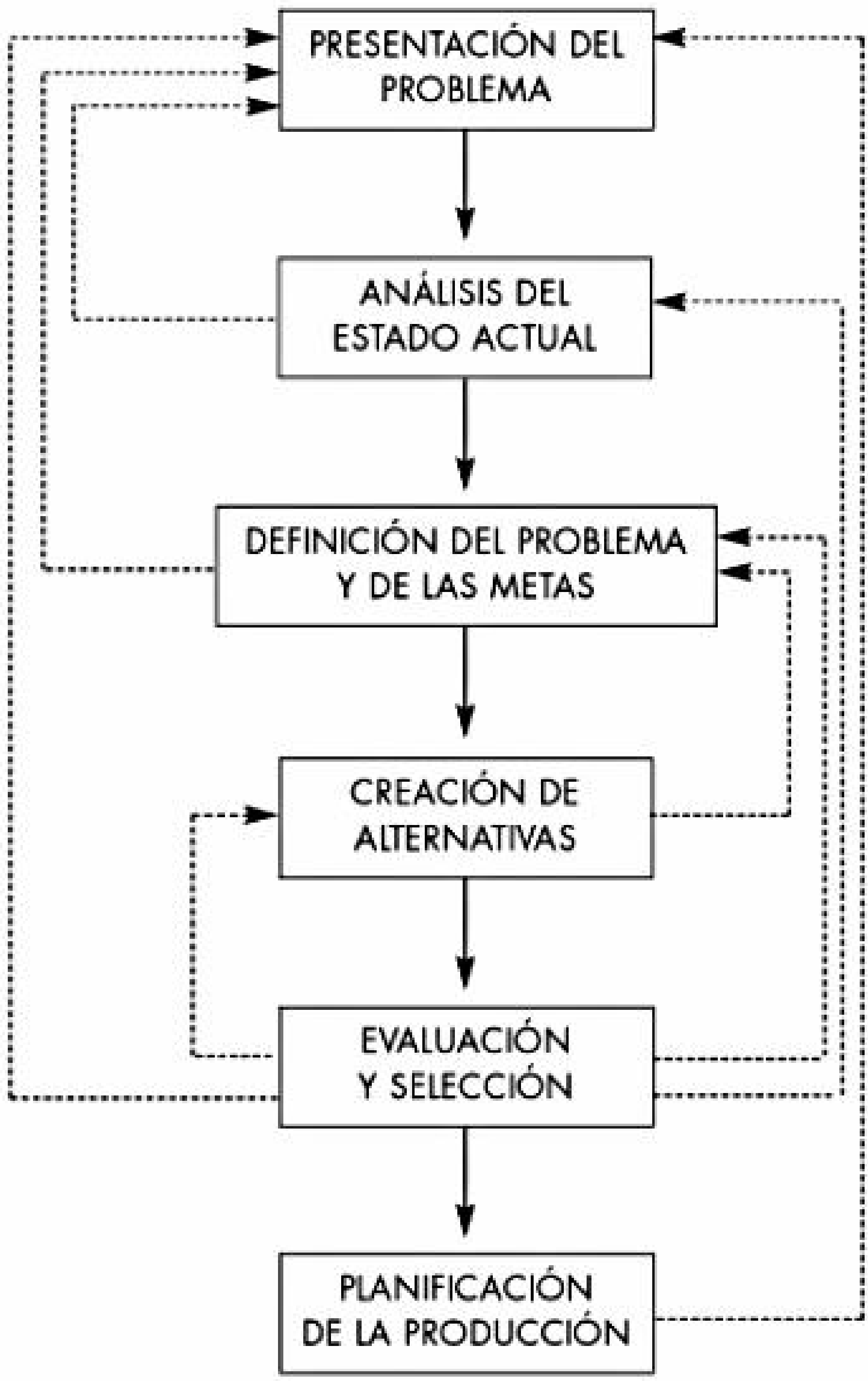

Figure 14. Model of the design process according to Hans Gugelot.

Information Stage:
Gather as much information as possible about who you are designing for.
Research the institution or context in which the design will be applied.
Research Stage:
Investigate the needs and context of the project.

Understand the restrictions and limitations.
Design Stage:
Carry out a typological study.
Rely on formal knowledge to generate design proposals.
Decision Stage:
Evaluate costs and benefits.
Conducts fundamental technological studies.
Calculation Stage:
Adjusts the design to standard norms and materials.
Consider the viability of production.
Construction Stage:
Build the prototype.
Conduct tests and assessments.

Results and discussion

It would be interesting to start with an analogy, Louis Sullivan (1856-1924) said that “form follows function” (Sullivan, 1896: 403-409), we could say that the designer's creative thinking follows the design method or methodology that he applies.

To do this, it is necessary to review the state of the art of the issue, which is equivalent to reviewing the existing bibliography on design methods and methodologies.

What is meant by the design method? All other things being equal, what is meant by the design methodology? Should we begin by explaining the scientific method and the various methodologies of scientific research?

It would be correct to start with the analysis of MC-14, which is a 14-stage scientific method[1]Which brings us to the next question: What is science?[2] [3]

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[1]The 14 stages of the MC-14 are:
Stage 1: Observation
Step 2: Is there a problem?
Stage 3: Objectives and planning
Stage 4: Search, exploration and evidence gathering
Stage 5: Creative generation and logical alternatives
Stage 6: Evaluating the evidence
Stage 7: Making hypotheses, conjectures and assumptions
Stage 8: Experimentation, testing and questioning of hypotheses
Step 9: Drawing conclusions
Stage 10: Extension or delay of statements or value judgments
Stage 11: Theory development (thesis) and submission for peer review
Stage 12: Creative, logical, non-logical and technical methods
Stage 13: Objectives of the scientific method
Stage 14: Attitudes and cognitive skills

[2] Science is an orderly system of structured knowledge that studies, investigates, and interprets natural, social, and human-made phenomena. Scientific knowledge is obtained through observation and experimentation in specific fields. This knowledge is organized and classified based on explanatory principles, whether theoretical or practical. From these principles, questions and reasoning are generated, hypotheses are formulated, scientific principles and laws are deduced, and theoretical models (scientific theories) and knowledge systems are constructed through a method or methodology of scientific research.

[3] Science considers and is based on experimental observation. This type of observation is organized through methods, models, and theories to generate new knowledge. To achieve this, criteria of truth and a research method are previously established. The application of these methods and knowledge leads to the generation of new knowledge in the form of concrete, quantitative, and verifiable predictions regarding past, present, and future observations. These predictions can often be formulated through reasoning and structured as general rules or laws, which explain the behavior of a system and predict how that system will behave under certain circumstances.

[4]Which is not so difficult to answer, since there is international consensus and the bibliography is consistent as to what is understood by modern science.
But answering the following question: What is scientific research methodology? This answer is much more complex because it requires asking: which classification or group of sciences (since there are several)? Well, we have formal sciences (logic) and exact sciences (mathematics) or factual sciences (empirical or experimental) such as the natural sciences (geology, biology, physics, chemistry) and the social-human sciences (anthropology, economics, sociology, psychology, history, architecture, art, and design). On the other hand, as part of the empirical sciences, we have applied sciences of R&D (Research + Technological Development), which has an interesting group of disciplines (all branches of engineering). What place does Industrial Design have within this classification?
The problem arises if the conclusions obtained from the testing (in the laboratory and with end users/consumers) contain design corrections that force us to return to stage (3) of Design Thinking or the innovation ideation stage, which requires a change in the (2) design hypotheses (or minimal changes while maintaining the hypotheses). The entire cycle must be restarted from stage (3) onwards: (3) ideate, (4) prototype until the new (5) final test. In which the design becomes definitive. This process can be cyclical with several returns.
It would be necessary to incorporate into Design Thinking: (a) computational flowchart feedback (such as software programming) so that the graphical representation resembles an algorithm or computational process in cases of rollback or correction of design errors. Also (b) to make a proper correlation with MC-14 of the "scientific method" and its stages (see this section in greater depth). Given that "there is nothing new under the sun" in Design Thinking and nothing—for the moment—surpasses the Scientific Method (tested worldwide and developed by academics and professionals from diverse fields).
It is recommended to integrate it into the MC-14.

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[4] Scientific knowledge is:
-Descriptive, explanatory and predictive.
-Critical and analytical.
-Methodical and systematic.
-Controllable.
-Unified.
-Logically consistent.
-Communicable through precise language.
-Aim.
-Provisional.

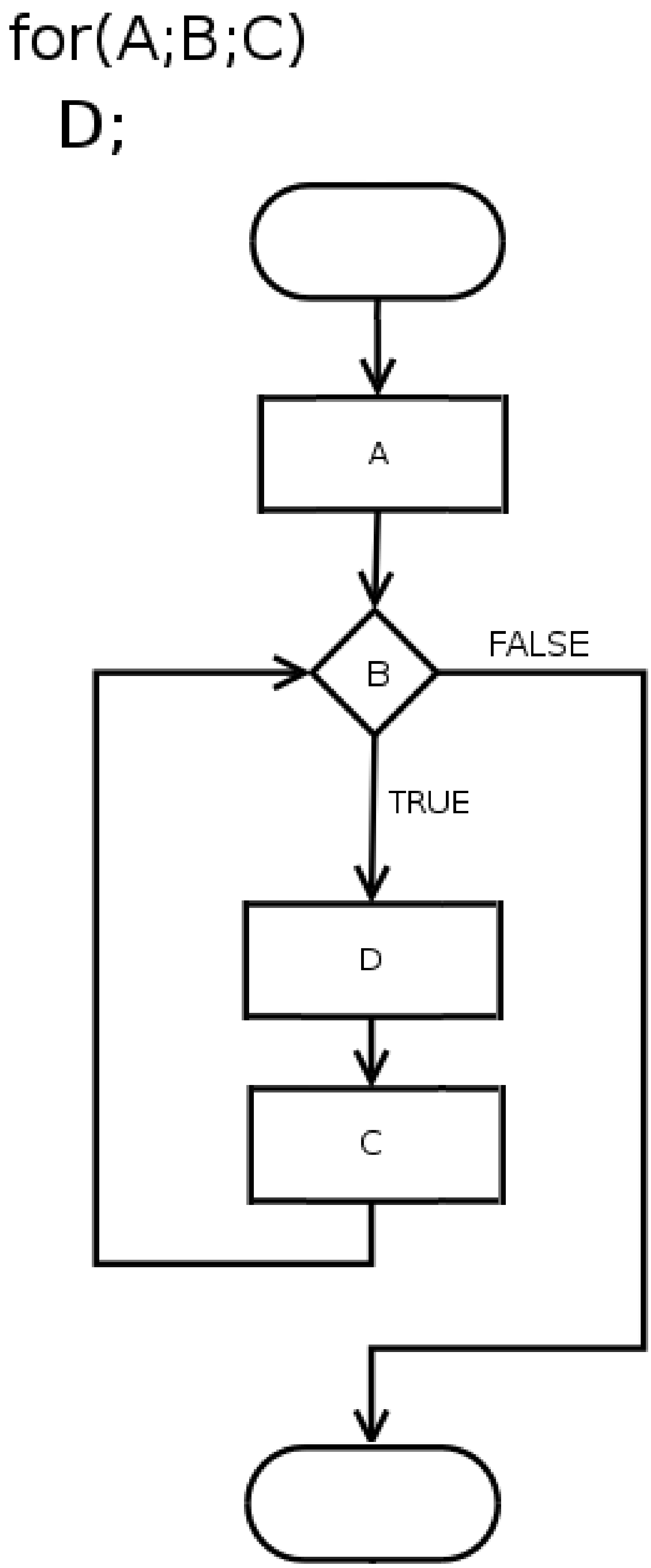


Figure 15. Activity flow diagram for a loop

Figure 16. This flowchart of an example by the author and design theorist would have a certain analogy with that described by Bruno Munari (1907-1998) in his book How are objects born? (Munari, Bruno. How are objects born? Trad. Carmen Artal Rodríguez. Editorial Gustavo Gili, SA Barcelona, 1983. p. 64).

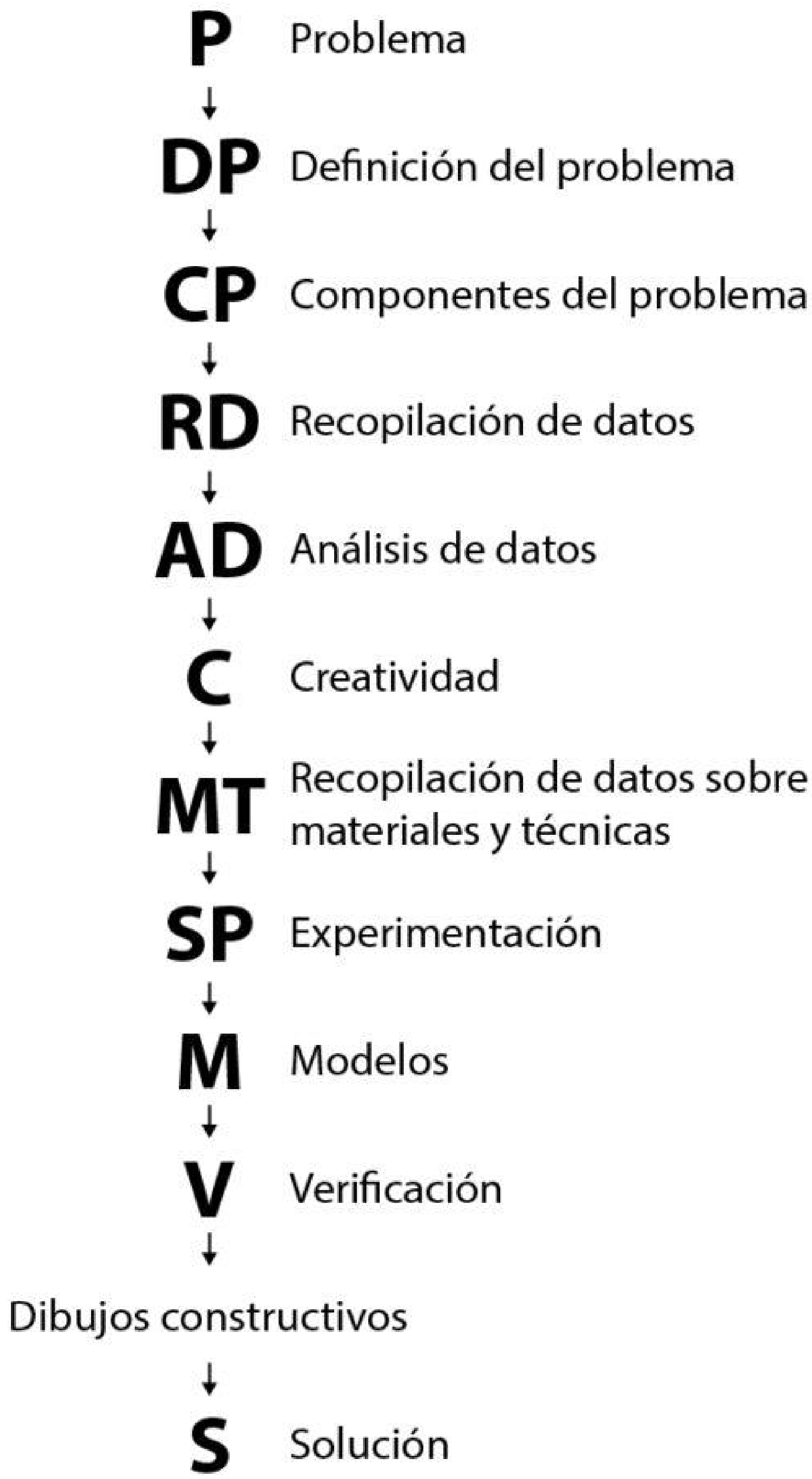


Figure 17. In the abstract, Bruno Munari's method has some of the computational flowchart developed by software analysts (computer science

graduates and engineers, programmers, systems analysts, etc.). But it lacks feedback. Bruno Munari's method is more linear.

Bruce Archer (1922–2005) developed a more detailed prescriptive model, summarized in the following figure. It includes interaction with the design process's external world, such as client input, the designer's training and experience, other sources of information, and so on. The outcome is, of course, the communication of a specific solution. This input and output are shown as external to the design process in the flowchart, which also features numerous feedback loops. Within the design process, Archer identified six types of activity:

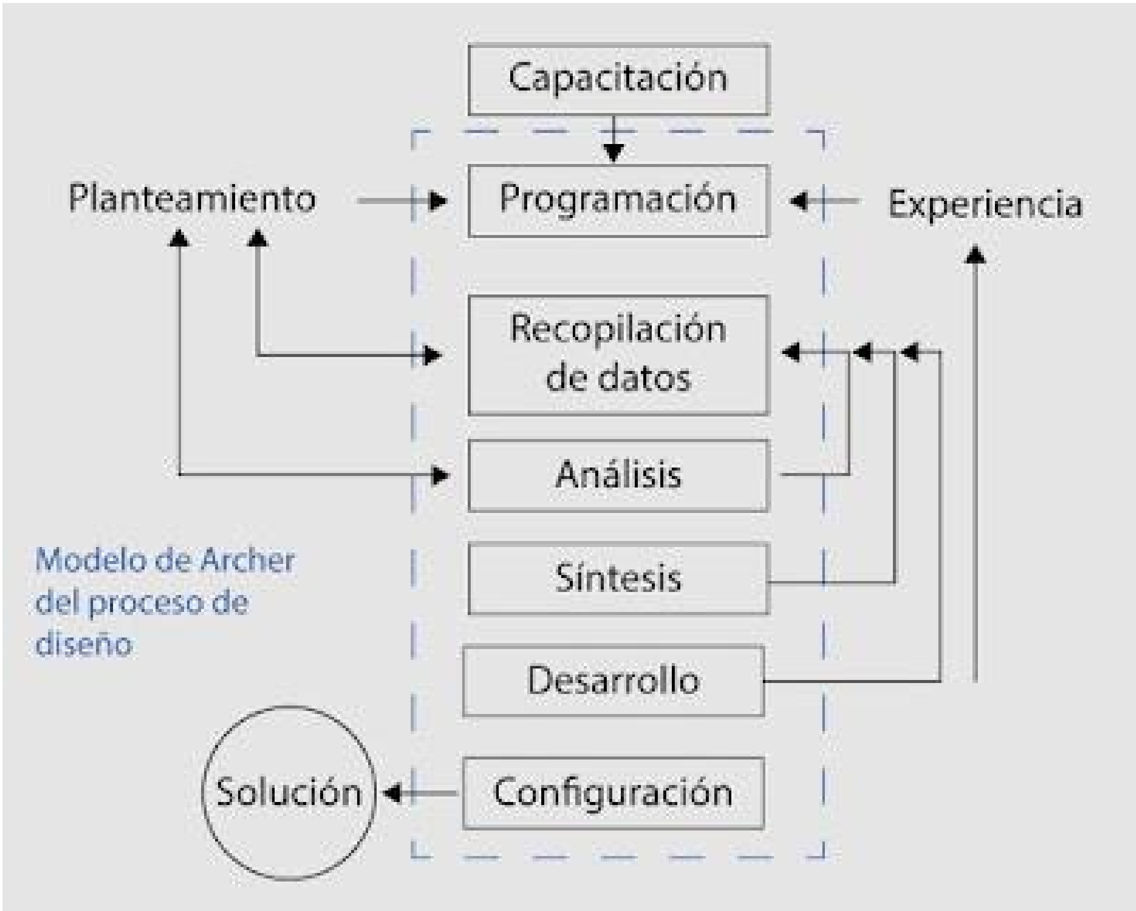


Figure 18. The diagram is analogous to a flowchart but is not exactly the same.

Programming - establishing crucial aspects; proposing a course of action. (An outline of what will be done.)
Data collection - collecting, sorting, and storing data.
Analysis – Identify secondary problems; prepare performance (or design) specifications; reevaluate the proposed program and estimates.
Synthesis- prepare sketches of design proposals.
Development – develop a prototype design or designs; prepare and conduct validation studies.
Communication - prepare manufacturing documentation.

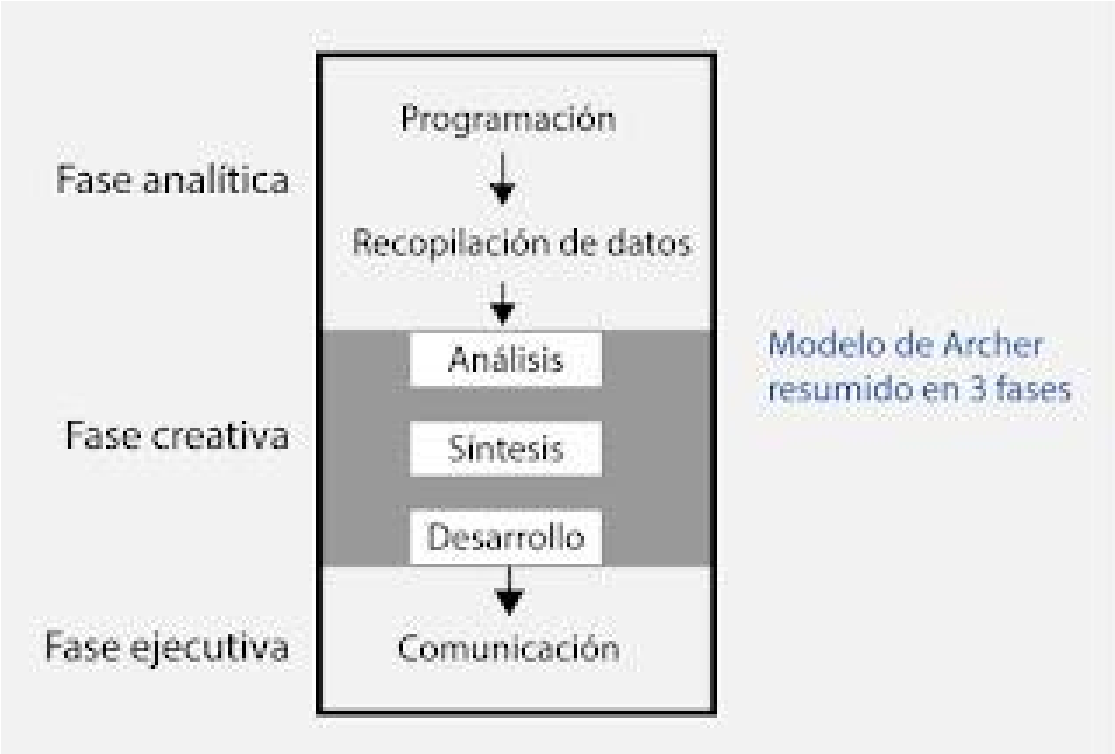


Figure 19. Archer summarized this as a three-phase process: analytical, creative, and executive (see figure).

He suggested that one of the special characteristics of the design process is that the analytical phase, with which it begins, requires objective observation and inductive reasoning, while the creative phase, which lies at its heart, requires participation, subjective judgment, and deductive reasoning. Once the crucial decisions are made, the design process continues with the execution of working drawings, programs, etc., in an objective and descriptive manner, as already mentioned. The design process is, in this way, a creative sandwich. The bread of objective and systematic analysis can be thick or thin, but the creative act is always there in the middle.

The Analytical Phase corresponds to the (1) empathize stage of Design Thinking.

The Creative Phase corresponds to the stages (2) define, (3) ideate, (4) prototype and the Executive Phase corresponds to the stage (5) test of Design Thinking.

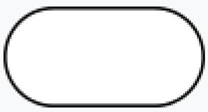
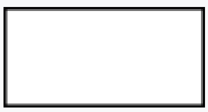
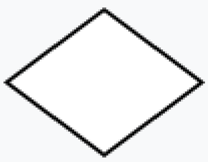
Archer has a conceptually similar spirit (not exactly the same as Bruno Munari's). What we need to do is integrate these methods into one.

On the other hand,The creative process can be defined as the main concepts oriented toward creativity and its potential in everyday life, business, and design. The barriers to creativity and the approach to it in education in our country are addressed. The creative process addressed in this first part is the traditional one addressed in Industrial Design Methodology courses and can be transferred to Design Thinking. The traditional creative process (Wallas, 2014) is considered to be defined by Graham Wallas in 1926 in his book The Art of Thinking. This is done in order to contrast the paradigm shift in creativity. Table 1 shows the stages of both paradigms.

Model	Design Thinking
Preparation	Empathize
Incubation	Define
Lightning	Devise
Verification	Prototype
Verification	Assess

Table 3: The traditional and modern paradigms of the creative process. Source: own elaboration.

The American National Standards Institute (ANSI) established standards for flowcharts and their symbols in the 1960s. The International Standards Organization (ISO) adopted ANSI symbols in 1970. The current standard, ISO 5807, was revised in 1985.

ANSI/ISO Form	Name	Description
	Flow line (Arrow)	It shows the order of operation of the processes. A line extending from one symbol to another points. Arrows are added if the flow is not the standard top-to-bottom, left-to-right flow.
	Terminal	Indicates the start or end of a program or subprocess. It is represented as an oval. They usually contain the word "Start" or "End," or some other phrase indicating the start or end of a process, such as "submit inquiry" or "receive product."
	Process	Represents a set of operations that change the value, shape, or location of data. Represented as a rectangle.
	Decision	Displays a conditional operation that determines which of two paths the program will take. The operation is typically a yes/no question or a true/false test. Represented as a diamond.

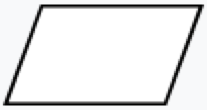
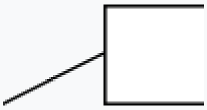
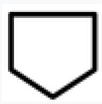
	Entrance	Indicates the process of entering data in the data entry form. Represented as a parallelogram.
	Exit	It indicates the process of outputting data, in the form of displaying results. Represented as a printed sheet of paper.
	Annotation (Comment)	Indicates additional information about a program step. Represented as an open rectangle with a line (which may be dotted) connecting it to the corresponding flowchart symbol.
	Predefined Process	It shows, by name, a process that has been defined elsewhere. It is represented as a rectangle with a double side on each side.
	Page Connector	Labeled connector pairs replace long or confusing lines on the diagram page. They are represented as small circles with a letter inside.
	Off-page connector	A connector tag for use when the target is another page. Represented in the shape of a pentagon.

Figure 20. My final proposal that integrates everything:

An illustrative example of the application of the flowchart is the following:

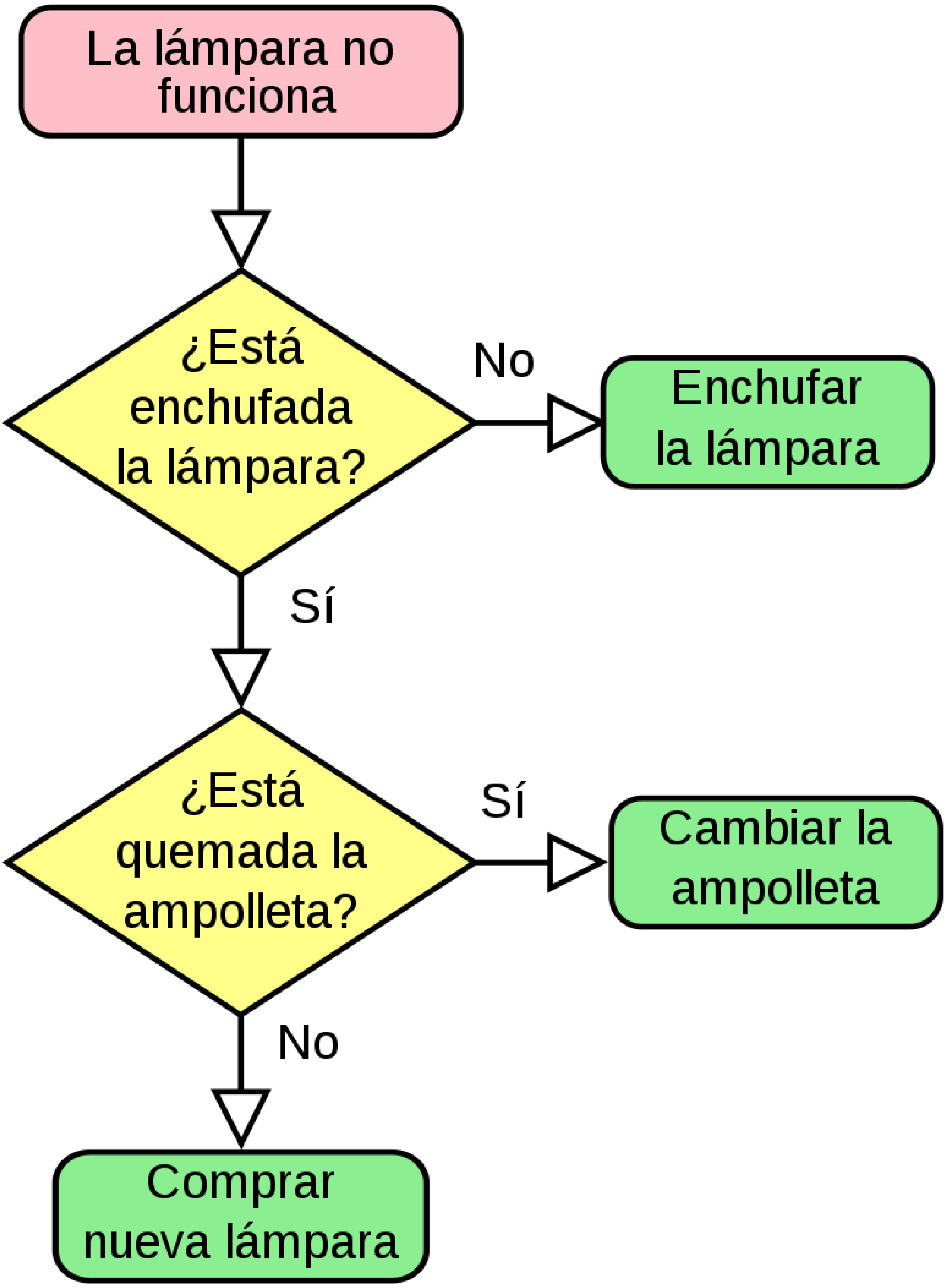


Figure 21. Attempts have been made to create flowchart models applied to Industrial Design, but they are not standardized, see the following example:

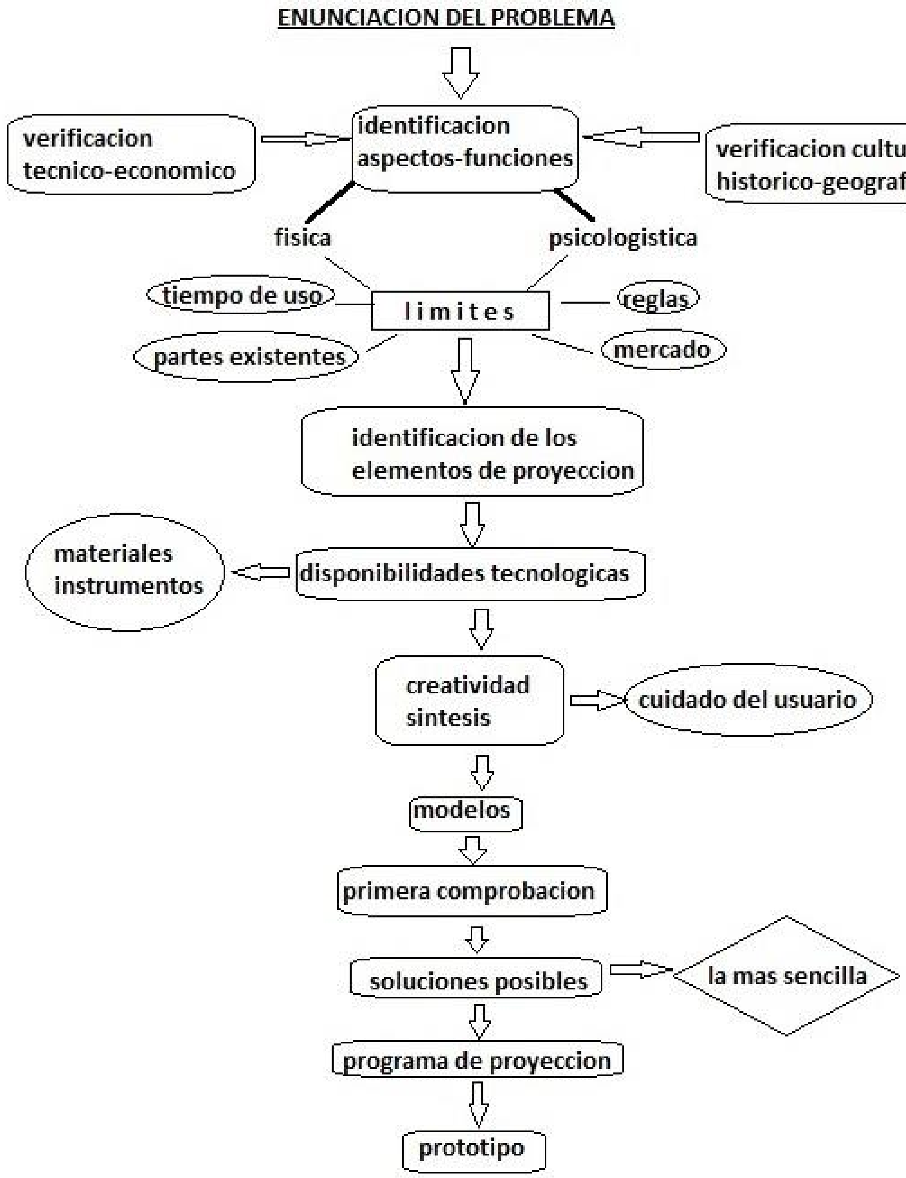


Figure 22. A typical Industrial Design methodology.

What is the difference between scientific research methodology and design methods?
There are some similarities between some methods that allow us to speak of methodological constants. To cite just a few examples, for example.
Asimow describes a general problem-solving process that he calls the design process and it also has its six (6) stages: (1) Analysis, (2) Synthesis, (3) Evaluation and decision, (4) Optimization, (5) Review and (6) Instrumentation.
Similarly, Archer describes a six (6) stage scheme: (1) programming, (2) data collection, (3) analysis, (4) synthesis, (5) development and (6) communication (67).
Fallon also develops a scheme of six (6) stages: (1) preparation, (2) information, (3) assessment, (4) creativity, (5) selection and (6) project.

For his part, Gugelot also describes six (6) stages in his development process: (1) Information stage, (2) Research stage, (3) Design stage, (4) Decision stage, (5) Calculation stage and (6) Model realization stage.
While the methodology of scientific research studies the procedures for approaching "scientific objects", while design methods study the procedures for approaching "design objects", both must be integrated in the following way in Design Thinking with a software-type design.

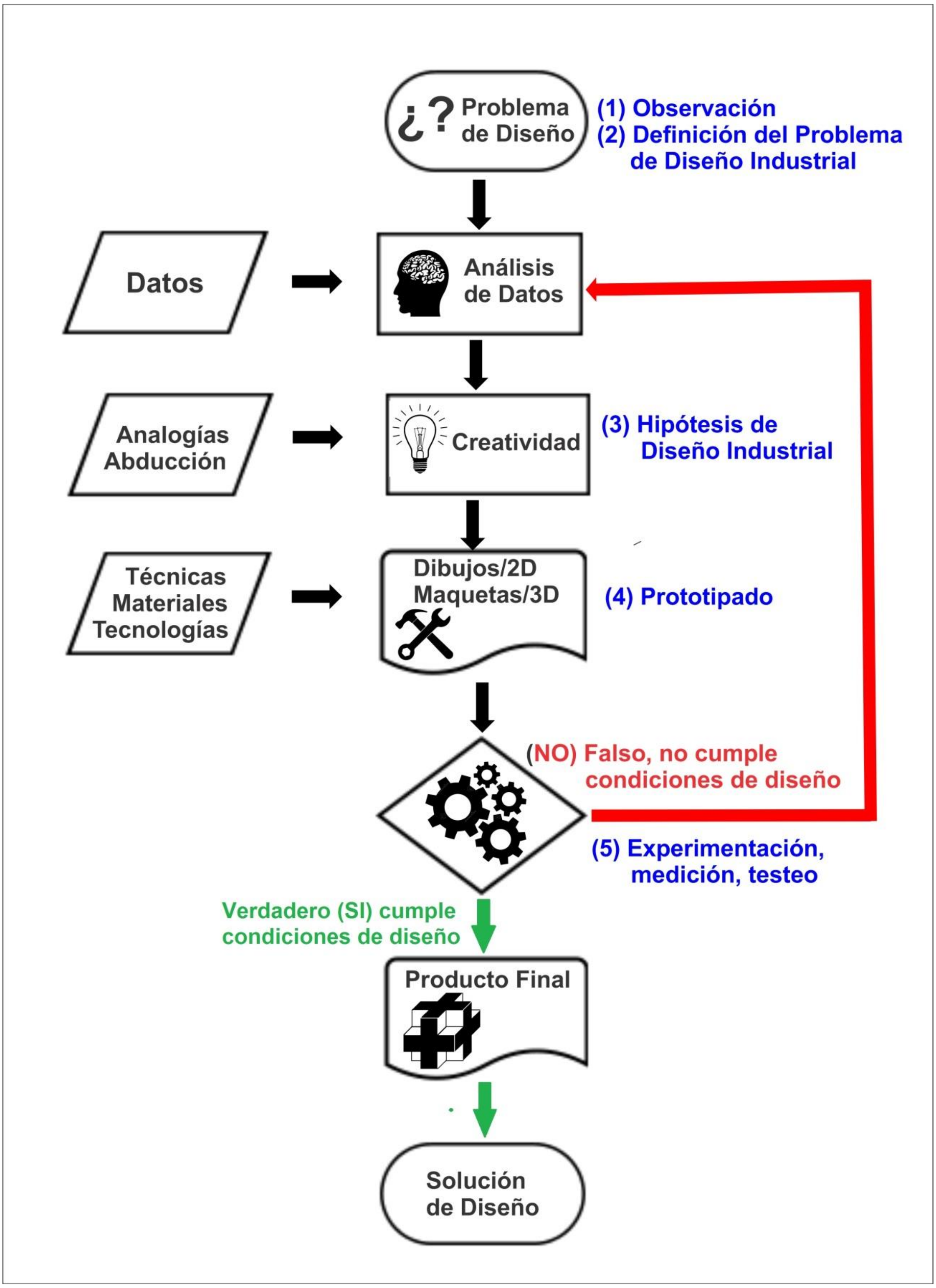


Figure 23. Analogy provides the design process with the capacity for objective abduction to weave and formulate hypotheses, relate facts, codify new links, and project these mental constructs two- or three-dimensionally. The software design image corresponds to the analogy between Design Thinking and the formal academic Industrial Design program.

Creativity follows a defined process: recognition, preparation, illumination, verification.
The research process is then summarized in the following steps:
-Definition of the research problem.
-Hypothesis (answer to the problem).
-Methodology and technique used in research methods (qualitative processing, hermeneutic or heuristic?)
-Analysis of methods:
    Hypothetical-deductive
    Inductive
    Abductive
-Data matrix design (cutting out the object of study):
    Unit of analysis.
    Variables.
    Variable values.
    Indicators.
    Dimension=Indicator/Procedure.
-Data collection work (field).
-Prosecution.
-Results and discussion.
-Conclusions.
-References and Bibliography.

Analogy (abduction) is vitally important for industrial designers. Someone should explain to them the reasons why they should pursue a doctorate.
Well, models of scientific reasoning have been described by epistemologists in terms of deductive or inductive inferences; but abductive inferences have received little attention. Explaining the processes of abductive inference and their usefulness for industrial designers is extremely useful for explaining problem-solving processes in the field of scientific research for a master's or doctorate degree in industrial design; when precisely what these professionals seek is to design, not write and research. Thus, scientific researchers, through abductive cognitive processes, can generate a wide range of new hypotheses that must then be demonstrated or validated, and among them, rationally decide which ones are capable of accounting for the observational data.
Abduction acquired its current meaning from Charles S. Peirce (Cambridge, Massachusetts, 1839-1914), understood as the inferential process that leads to the invention, discovery, or creation of a hypothesis; a proposal that is then inscribed as an attempt to construct a scientific "logic of discovery."
For Peirce, abduction, or retroduction, is an inferential process related to hypothesis generation, whether in scientific reasoning or in ordinary thought. It is the reasoning process through which new ideas, explanatory hypotheses, and scientific theories are generated. Thus, rather than deduction and induction,

abduction is the primary mode of inference, since if new ideas are the fruit of abduction, then it constitutes the first step in all research.
Peirce outlined his proposals in a series of articles published between 1877 and 1878 in the popular Science Monthly, under the general title "Illustrations of the Logic of Science." The last of these, "Deduction, Induction, and Hypothesis," contains an exposition of the three modes of inference.
Peirce exemplified the three modes of inference by means of some “beans” (legume, bean or kidney bean).
But how do we make industrial designers understand this?
Let's see it with an example

DEDUCTION:
All the beans in this bag are white [Rule]
These beans are from this sack [Case]
(Therefore)
These beans are white [Result]

INDUCTION:
These beans are from this sack [Case]
These beans are white [Result]
(Therefore)
All the beans in this bag are white
[Ruler]

ABDUCTION:
All the beans in this bag are white [Rule]
These beans are white [Result]
(Therefore)
These beans are from this sack
[Case]

Example for industrial designers:
An example of beans is used to illustrate the logic of scientific research for industrial designers.

DEDUCTION:
If the fuse is blown, then the dryer won't work [Rule]
The fuse is blown [Case]
(Therefore)
the dryer doesn't work [Result]

INDUCTION:
The fuse is blown [Case]
The dryer does not work [Result]
(Therefore)
If the fuse is blown, then the dryer won't work [Rule]

ABDUCTION:
The dryer doesn't work [Made to explain]
If the fuse is blown, then the dryer will not work [Theoretical Framework]

(Therefore)
This fuse is probably blown [Hypothesis]

Ultimately, abduction is important in the context of scientific discovery and hypothesis formulation, in heuristics, and in what every doctoral student must understand to become a good scientist and "leapfrog" from a mere undergraduate degree to a graduate degree. This is the qualitative difference.
Those who don't follow the path will never understand. Those who don't study scientific research methodology and epistemology of science will never understand it either.

Debate:
The analysis provided shows an interesting connection between the stages of Design Thinking and the scientific process of technological development (R&D&I) followed by industrial designers and Science and Technology (S&T) researchers. Let's summarize the correlation identified:
-*Empathize (Design Thinking) and Observation (Scientific Method):*The empathizing stage relates to observation in the scientific method, where the goal is to understand the needs of users/clients or identify relevant phenomena.
-*Define (Design Thinking) and Hypothesis (Scientific Method):*The defining stage is associated with hypothesis formulation in the scientific method, where the problem or question to be addressed is clearly established.
-*Design Thinking and Innovation Ideation (Scientific Method):*The ideation stage in Design Thinking relates to the generation of design hypotheses in the scientific method, where potential solutions or designs are proposed.
-*Prototyping (Design Thinking) and Experimentation and Measurement (Scientific Method):*The prototyping stage connects with the experimentation and measurement phase in the scientific method, where an initial model is created to evaluate its viability.
-*Test (Design Thinking) and Testing (Scientific Method):*The testing stage in Design Thinking corresponds to the experimentation and measurement phase in the scientific method, where the prototype is evaluated under controlled conditions.
-*Conclusions (Design Thinking) and Falsifiability of Design Hypotheses (Scientific Method):*Conclusions in Design Thinking relate to the evaluation of the falsifiability of design hypotheses in the scientific method.
-*Reproducibility or Repeatability (Design Thinking) and Peer Review (Scientific Method):*Reproducibility and repeatability in Design Thinking are associated with peer review in the scientific method, where other designers and engineers evaluate and validate the product's industrial manufacturing method.
This analysis highlights the convergence of creative and scientific processes in the development of industrial design projects, showing how both approaches share essential elements for achieving successful results and validation in the academic or scientific community.
The difference between scientific research methodology and design methods lies in the approach and objectives of each, although there are similarities in the stage structures used by various authors in both fields.
Scientific research methodology focuses on the study of the procedures and approaches used to address "scientific objects." It involves a rigorous and systematic process for investigating phenomena, testing hypotheses, and

generating scientific knowledge. It generally follows a classical structure that includes stages such as observation, hypothesis formulation, experimentation, data analysis, conclusions, publication, and peer review.

Design methods, on the other hand, focus on procedures for addressing "design objects." They are more concerned with creating practical and functional solutions to specific problems. Although design methods vary widely, many share some common stages, as exemplified by the authors mentioned above: analysis, synthesis, evaluation and decision-making, optimization, review, and implementation (in the case of Asimow).

To integrate both approaches into Design Thinking, which you mention has a software-type design, the following can be considered:

-*Understanding the Problem (Similar to Analysis):*In Design Thinking, deep understanding of the problem aligns with the analysis stage.

-*Generation of Ideas (Similar to Synthesis and Creativity):*The ideation phase in Design Thinking can be linked to the synthesis and creativity stages in design methods.

-*Prototyping and Testing (Similar to Evaluation and Decision):*The prototyping and testing stages in Design Thinking share similarities with evaluation and decision-making in design methods.

-*Iteration (Similar to Review):*Continuous iteration, common in Design Thinking, resembles review in design methods.

-*Implementation (Similar to Model Realization):*The implementation phase in Design Thinking can be related to the realization of the model in design methods.

The key to effective integration is understanding how each stage contributes to the overall process and how they can be adapted according to the project context, whether in scientific research or design.

Autor/Metodología	Empatizar	Definir	Idear	Prototipar	Probar
Munari, Bruno (1971)	Investigación	Programa	Concepto	Materialización	Verificación
Papanek, Victor (1984)	Definición del problema	Investigación	Estrategias alternativas	Prototipo	Evaluación
Jones, Christopher (1970)	Divergencia	Transformación	Convergencia	Evaluación preliminar	Optimización
Löbach, Bernd (1976)	Análisis del problema	Especificación de requisitos	Desarrollo de conceptos	Prototipos	Evaluación
Dixon, Tom (2000)	Brief	Concepto inicial	Desarrollo	Prototipos	Revisión
Earl, Harley J. (1950)	Investigación del mercado	Diseño preliminar	Modelo a escala	Prototipo	Pruebas
Krick, Edward (1969)	Análisis de necesidades	Diseño conceptual	Desarrollo de productos	Prototipos	Evaluación
Asimow, Morris (1962)	Requerimientos	Síntesis	Análisis	Modelado	Evaluación
Archer, Bruce (1965)	Análisis	Diseño	Desarrollo	Prototipado	Evaluación

Figure 24. The Design Thinking methodology, like many others, consists of five stages. However, the MC-14 scientific method has eight stages, indicating a more detailed and structured process.

Munari, Bruno (1971): His methodology includes research to understand the problem, the creation of a work program, the development of concepts, the materialization of these concepts in prototypes and the final verification.
Papanek, Victor (1984): Papanek emphasizes the definition of the problem, followed by in-depth research, generation of alternative strategies, prototyping and evaluation of the results.
Jones, Christopher (1970): This method focuses on an initial phase of divergence to explore all possibilities, followed by transformation and convergence toward viable solutions, preliminary evaluation, and optimization.
Löbach, Bernd (1976): It starts with an analysis of the problem, specifies the requirements, develops concepts, creates prototypes and ends with the evaluation of these prototypes.
Dixon, Tom (2000): Start with a brief, develop an initial concept, proceed to detailed development, create prototypes and carry out revisions.
Earl, Harley J. (1950): His process includes market research, preliminary design, scale modeling, prototyping, and testing.
Krick, Edward (1969): Focuses on needs analysis, conceptual design, product development, prototyping and evaluation.
Asimow, Morris (1962): Includes requirements, information synthesis, detailed analysis, solution modeling and evaluation.

Archer, Bruce (1965): His methodology covers analysis, design, development, prototyping and evaluation.

All methodologies, like Design Thinking, can be divided into five main stages:

(1) Empathize: At this stage, the goal is to thoroughly understand the users' needs, desires, and problems. This is achieved through techniques such as interviews, observation, and surveys, allowing the design team to put themselves in the user's shoes and understand their perspective.

(2) Define: Using the information obtained in the empathy stage, the problem or challenge you want to address is clearly defined. This stage involves synthesizing the information to identify patterns and developing a user-centered problem statement.

(3) Ideation: In this stage, a wide variety of ideas and possible solutions to the defined problem are generated. Using creativity techniques such as brainstorming, the design team explores all options without restrictions, encouraging innovation and outside-the-box thinking.

(4) Prototyping: The most promising ideas are turned into tangible prototypes. These prototypes can range from basic models to more detailed versions and serve to explore how solutions might work in practice. The goal is to iterate quickly and learn from mistakes and successes.

(5) Testing: Prototypes are tested with real users to gather feedback and evaluate their effectiveness. This stage involves observing how users interact with the prototypes, collecting their comments, and refining solutions based on this feedback. It's an iterative process that can lead to new ideas and adjustments until the best possible solution is achieved.

These stages, although presented sequentially, are usually iterative and can be repeated several times throughout the design process.

The MC-14 scientific method has eight stages. They are listed below, along with a brief description of each:

(1) Observation: Initial analysis of the problem or need. This stage involves observing and gathering relevant information to clearly identify the problem to be solved.

(2) Hypothesis: Proposal of solutions based on observation. In this stage, hypotheses are formulated that can explain the problem and that will guide the experimentation process.

(3) Experimentation: Prototyping and initial testing. Controlled experiments are conducted to test proposed hypotheses and collect data.

(4) Measurement: Collection of quantitative and qualitative data. Prototype performance is measured and analyzed, gathering useful information to evaluate the validity of the hypotheses.

(5) Falsifiability: Verification and refutation of hypotheses. This stage verifies whether the hypotheses can be refuted by the data obtained, ensuring their validity.

(6) Reproducibility: Validation of the process by other designers/engineers. This ensures that others can replicate the experiments and obtain the same results, ensuring the consistency of the method.

(7) Repeatability: The ability to mass-produce the design. This assesses whether the design can be consistently repeated in larger-scale production.

(8) Publication: Documentation and peer review. Finally, the findings are documented and published so that others can review and validate the work.

Debate.

Using Artificial Intelligence (GPT Chat, DeepSeek, Qwen) to analyze this text and compare the information with its Databases, the following Python script was created, hosted on GitHub and deployed with Streamlit.

The provided file contains a Python script that uses the Streamlit library to create an interactive application describing and comparing two methodologies: the Scientific Method MC-14 and the Industrial Design Method (IDM). The script sets up the page with a broad title and layout, defines dictionaries with detailed descriptions of each stage of both methodologies, and uses Mermaid to render interactive flowcharts with pop-ups explaining each step on hover or click. The application allows users to select between MC-14 and IDM, displaying diagrams structured according to the ISO 5807:1985 standard, with descriptive icons and practical examples to facilitate understanding.

The MC-14, a 14-stage scientific method, guides research processes through curious observation, problem posing, literature review, hypothesis formulation, experimental design, data collection and analysis, conclusions, report writing, peer review, publication, and feedback. The MPDI, on the other hand, focuses on industrial design, integrating stages such as user empathy, problem definition, trend research, ideation, 3D prototyping, technical evaluation, iteration, documentation, user validation, production, and marketing strategies. Both methods share an iterative approach but differ in their orientation: the MC-14 prioritizes hypothetical-deductive validation and academic rigor, while the MPDI emphasizes creative problem-solving, technical feasibility, and end-user satisfaction.

The project's objective was to synthesize theory and practice into an accessible tool, using AI to refine technical descriptions and ensure alignment with academic frameworks. Usability was optimized with visual adjustments, detailed tooltips, and concrete examples, such as a 67% reduction in motor energy consumption. Achievements include the integration of ISO standards, clarity in the representation of complex processes, and adaptability for multiple audiences. Limitations include challenges in the responsive design of pop-up windows, while future improvements aim to address multilingualism, data export, and connection to external databases. In conclusion, the tool demonstrates how technology and AI can facilitate the teaching and application of scientific and design methodologies, highlighting the convergence of academic rigor and practical, user-centered approaches.

Python script.

```
import json

# Initial page setup
st.set_page_config(page_title="MC-14 and MPDI", layout="wide")

# Author Information (Blank Text)
st.markdown("""
```

```
<div style='background-color: #2D2D2D; padding: 20px; border-radius: 10px; margin-bottom: 20px;'>
   <h2 style='color: white;'>□ Author</h2>
   <p style='color: white;'>© 2025 <strong>Ibar Federico Anderson, Ph.D., Master, Industrial Designer</strong></p>
   <div style='display: flex; justify-content: space-between; margin-top: 10px;'>
      <div>
         <p style='color: white;'><img src="https://upload.wikimedia.org/wikipedia/commons/c/c7/Google_Scholar_logo.svg" style="height: 20px; vertical-align: middle;"> <a href="https://scholar.google.com/citations?user=mXD4RFUAAAAJ&hl=en" target="_blank" style='color: white;'>Google Scholar</a></p>
         <p style='color: white;'><img src="https://upload.wikimedia.org/wikipedia/commons/0/06/ORCID_iD.svg" style="height: 20px; vertical-align: middle;"> <a href="https://orcid.org/0000-0002-9732-3660" target="_blank" style='color: white;'>ORCID</a></p>
      </div>
      <div>
         <p style='color: white;'><img src="https://upload.wikimedia.org/wikipedia/commons/5/5e/ResearchGate_icon_SVG.svg" style="height: 20px; vertical-align: middle;"> <a href="https://www.researchgate.net/profile/Ibar-Anderson" target="_blank" style='color: white;'>Research Gate</a></p>
         <p style='color: white;'><img src="https://mirrors.creativecommons.org/presskit/icons/cc.svg" style="height: 20px; vertical-align: middle;"><img src="https://mirrors.creativecommons.org/presskit/icons/by.svg" style="height: 20px; vertical-align: middle;"> <a href="https://creativecommons.org/licenses/by/4.0/" target="_blank" style='color: white;'>CC BY 4.0 License</a></p>
      </div>
   </div>
</div>
""", unsafe_allow_html=True)

# Application title with ISO 5807:1985 (Black text)
st.markdown("""
<h1 style='text-align: center; color: black;'>Select a methodology</h1>
Flowcharts are based on the <strong>ISO 5807:1985</strong> standard, which defines graphical conventions for representing logical processes and data structures.
""", unsafe_allow_html=True)

# Custom buttons to select methodology
col1, col2 = st.columns(2)

with col1:
   if st.button("MC-14: Scientific Method", key="mc14_button", help="Select this option to view the Scientific Method flow"):
      st.session_state["selected_option"] = "MC-14: Scientific Method"

with col2:
   if st.button("MPDI: Industrial Design", key="mpdi_button", help="Select this option to view the Industrial Design flow"):
      st.session_state["selected_option"] = "MPDI: Industrial Design"

# Extended descriptions for MC-14
mc14_descriptions = {
   "□ Curious Observation": """
      Curious observation is the starting point of the scientific method. It involves identifying unusual phenomena or patterns that spark investigative interest. This step involves paying attention to details that others might overlook.
   """,
```

```
    "? Problem Statement": """
        The problem statement consists of formulating a clear and specific question to guide the investigation. It must be precise enough to allow for a practical and relevant solution.
    """,
    "□ □ Literature Review": """
        The literature review involves exploring previous studies, theories, and existing data related to the problem. This step helps contextualize the problem within current knowledge and avoid unnecessary duplication.
    """,
    "□ Hypothesis": """
        A hypothesis is a predictive statement that attempts to explain an observed phenomenon. It must be testable through experiments and provide a solid basis for research.
    """,
    "□ □ Experimental Design": """
        Experimental design includes planning methods, tools, and procedures for systematically collecting data. This step ensures that the results are valid and reproducible.
    """,
    "□ Data Collection": """
        Data collection involves implementing planned methods to obtain relevant information. This process must be rigorous and follow established protocols to ensure data quality.
    """,
    "□ □ Data Analysis": """
        Data analysis includes the statistical or qualitative interpretation of the collected data. This step seeks to identify significant patterns, trends, or relationships that support or refute the hypothesis.
    """,
    "✅Conclusion": """
        The conclusion assesses whether the results obtained support the initial hypothesis. This step may also generate new questions or adjustments to the theoretical framework.
    """,
    "□ Report Writing": """
        Writing a report formally documents the entire research process, including objectives, methods, results, and conclusions. It is essential for scientific communication.
    """,
    "□ □ Peer Review": """
        Peer review is a critical process in which external experts evaluate the report to ensure its rigor and validity. This step enhances the quality and credibility of the work.
    """,
    "□ □ Publication": """
        Publication disseminates the results in scientific journals or at specialized conferences. This step allows other researchers to access and build upon the work.
    """,
    "□ Feedback": """
        Feedback generates new questions, applications, or improvements to the research process. This ongoing cycle fosters the advancement of scientific knowledge.
    """,
    "□ End": """
        It represents the end of the investigative cycle. This is where the processes are concluded and preparations are made for possible new investigations based on the results obtained.
    """,
    "□ Hypothesis Review": """
        If the hypothesis is not proven, this step allows it to be reformulated or adjusted based on the data collected, in order to attempt validation again.
    """,
}

# Extended descriptions for MPDI
mpdi_descriptions = {
    "□ Empathize and Contextualize": """
```

Empathy involves deeply understanding the needs, desires, and limitations of end users. This step also includes analyzing the social, cultural, and environmental context in which the product will be used.
""",
"❓ Define the Problem": """
Defining the problem involves clearly identifying what need or challenge you're trying to solve. This step should be specific and focus on users and their interactions with the environment.
""",
"□□ □ □ □ Web Research and DeepSearch": """
Web research includes searching for current trends, innovative materials, and similar cases. This stage uses advanced digital tools to gather relevant information.
""",
"□ ✨Ideation and Conceptualization": """
Ideation is a creative process that generates multiple potential solutions to a problem. Techniques such as brainstorming, mind mapping, and rapid prototyping are used to explore ideas.
""",
"✏ □ □ □ Sketches, 2D Renders and 3D Prototypes": """
Initial sketches and prototypes allow you to visualize and explore forms, functions, and usability. This step is key to transforming abstract ideas into tangible concepts.
""",
"□ □ Technical Evaluation": """
The technical evaluation analyzes the design's feasibility from technical, economic, and usability perspectives. This step ensures that the product is functional, safe, and cost-effective.
""",
"□ Iteration and Refinement": """
Iteration involves improving the design based on testing and feedback. This cyclical process ensures that the final product is optimal and meets user expectations.
""",
"□ Technical Documentation": """
Technical documentation includes detailed specifications, drawings, and user manuals. This step is essential for the production and maintenance of the product.
""",
"□ User Validation": """
User validation tests the product in real-world contexts to verify its functionality, aesthetics, ergonomics, and acceptance. This step ensures that the design meets the user's needs.
""",
"□ □ Production and Manufacturing": """
Production and manufacturing involve the implementation of the design in an industrial setting. This step includes the selection of materials, tools, and processes to create the final product.
""",
"□ Launch": """
Launch involves introducing the product to the market. This step includes marketing, distribution, and technical support strategies to ensure successful adoption.
""",
"□ □ □ Communication and Marketing for Users": """
Consumer communications and marketing focuses on promoting the product and generating interest among consumers. This step includes advertising campaigns, social media, and events.
""",
"□ End": """
It marks the conclusion of the industrial design process. Here, the overall success of the product is evaluated, and future iterations or improvements are considered.
""",
"□ Design Review": """
When a design is not approved in the documentation phase, this step allows you to return to the sketch stage to make substantial adjustments and improvements.
""",

```
}

# Flowcharts in Mermaid with longer, black arrows
mc14_diagram = """
%%{init: {'theme': 'base', 'themeVariables': { 'fontFamily': 'arial', 'fontSize': '20px' }}}%%
TD flowchart
    A([□ Curious Observation]) -->|" "| B[❓ Problem Statement]
    B -->|" "| C[/□ □ Literature Review/]
    C -->|" "| D{□ Hypothesis}
    D -->|"Formulation"| E[□ □ Experimental Design]
    E -->|" "| F([□ Data Collection])
    F -->|" "| G[[□ □ Data Analysis]]
    G -->|" "| H{ ✅Conclusion}
    H -->|"□ Supports Hypothesis"| I[/□ Report Writing/]
    H -->|"□ ❌Not Supported"| J[[□ Hypothesis Review]]
    J -->|" "| E
    I -->|" "| K((□ □ Peer Review))
    K -->|" "| L[(□ □ Post)]
    L -->|" "| M([□ Feedback])
    M -->|"New Questions"| A
    M -->|"□ End of Process"| N([□ End])

    classDef default fill:#3498db,stroke:#2980b9,color:white,stroke-width:2px
    classDef round fill:#e74c3c,stroke:#c0392b,color:white,cursor:pointer
    classDef diamond fill:#2ecc71,stroke:#27ae60,color:white,cursor:pointer
    classDef parallel fill:#9b59b6,stroke:#8e44ad,color:white,cursor:pointer
    classDef circle fill:#f1c40f,stroke:#f39c12,color:white,cursor:pointer
    classDef database fill:#1abc9c,stroke:#16a085,color:white,cursor:pointer

    linkStyle default stroke:#000000,stroke-width:3px

    class A,F,M,N round
    class D,H diamond
    class G,J parallel
    class K circle
    class L database
"""

mpdi_diagram = """
%%{init: {'theme': 'base', 'themeVariables': { 'fontFamily': 'arial', 'fontSize': '20px' }}}%%
TD flowchart
    A([□ Empathize and Contextualize]) -->|" "| B[/❓ Define the Problem/]
    B -->|" "| C[/□□ □ □ □ Web Research and DeepSearch/]
    C -->|" "| D{□ ✨Ideation and Conceptualization}
    D -->|"Generation"| E[✏ □ □ □ Sketches, 2D Renders and 3D Prototypes]
    E -->|" "| F([□ □ Technical Evaluation])
    F -->|" "| G[[□ Iteration and Refinement]]
    G -->|" "| H{□ Technical Documentation}
    H -->|"□ Documentation"| I[/□ User Validation/]
    H -->|"□ Not Approved ❌"| J[[□ Design Review]]
    J -->|" "| E
    I -->|" "| K((□ □ Production and Manufacturing))
    K -->|" "| L[(□ Launch)]
    L -->|" "| M([□ □ □ Communication and Marketing for Users])
    M -->|"New Improvements"| A
    M -->|"□ End of Process"| N([□ End])

    classDef default fill:#3498db,stroke:#2980b9,color:white,stroke-width:2px
    classDef round fill:#e74c3c,stroke:#c0392b,color:white,cursor:pointer
    classDef diamond fill:#2ecc71,stroke:#27ae60,color:white,cursor:pointer
```

```
    classDef parallel fill:#9b59b6,stroke:#8e44ad,color:white,cursor:pointer
    classDef circle fill:#f1c40f,stroke:#f39c12,color:white,cursor:pointer
    classDef database fill:#1abc9c,stroke:#16a085,color:white,cursor:pointer

    linkStyle default stroke:#000000,stroke-width:3px

    class A,F,M,N round
    class D,H diamond
    class G,J parallel
    class K circle
    class L database
"""

def render_mermaid(diagram, descriptions):
    # Prepare descriptions for JavaScript
    descriptions_json = json.dumps({k: v.strip() for k, v in descriptions.items()})

    # HTML with extra space and fixed tooltips
    html = f"""
    <script src="https://cdn.jsdelivr.net/npm/mermaid/dist/mermaid.min.js"></script>
    <div style="padding-bottom: 400px;">
        <div class="mermaid">
            {diagram}
        </div>
    </div>

    <div id="tooltip-box" style="display: none; position: fixed; bottom: 40px; left: 50%; transform: translateX(-50%);
                                width: 90%; max-width: 1200px; background-color: #34495e; colour: white;
                                padding: 35px; border-radius: 15px; box-shadow: 0 0 30px rgba(0,0,0,0.6); z-index: 1000;">
        <h3 id="tooltip-title" style="margin-top: 0; border-bottom: 2px solid #fff; padding-bottom: 15px; font-size: 32px; font-weight: bold;"></h3>
        <p id="tooltip-text" style="margin: 20px 0 0 0; font-size: 24px; line-height: 1.7;"></p>
    </div>

    <div id="scroll-indicator" style="position: fixed; right: 20px; bottom: 80px;
                                     background-color: rgba(52, 73, 94, 0.8); colour: white; padding: 10px;
                                     border-radius: 8px; animation: press 2s infinite;">
        ⬇ Swipe to see more content
    </div>

    <style>
        @keyframes pulse {{
            0% {{ opacity: 0.7; }}
            50% {{ opacity: 1; }}
            100% {{ opacity: 0.7; }}
        }}

        /* Customizing the scrollbar */
        ::-webkit-scrollbar {{
            width: 12px;
            height: 12px;
        }}

        ::-webkit-scrollbar-track {{
            background: #f1f1f1;
            border-radius: 10px;
        }}
```

```
    ::-webkit-scrollbar-thumb {{
        background: #3498db;
        border-radius: 10px;
    }}

    ::-webkit-scrollbar-thumb:hover {{
        background: #2980b9;
    }}
</style>

<script>
    // Initialize Mermaid
    mermaid.initialize({{ startOnLoad: true }});

    // Wait for the DOM to be ready
    document.addEventListener('DOMContentLoaded', function() {{
        // Allow time for Mermaid to fully render
        setTimeout(function() {{
            // References to DOM elements
            const tooltipBox = document.getElementById('tooltip-box');
            const tooltipTitle = document.getElementById('tooltip-title');
            const tooltipText = document.getElementById('tooltip-text');
            const scrollIndicator = document.getElementById('scroll-indicator');

            // Node descriptions
            const descriptions = {descriptions_json};

            // Function to handle clicks on nodes
            function handleNodeClick(event) {{
                // Get the text of the node
                const nodeText = event.currentTarget.textContent.trim();

                // If there is a description for this node
                if (descriptions[nodeText]) {{
                    // Show tooltip with description
                    tooltipTitle.textContent = nodeText;
                    tooltipText.textContent = descriptions[nodeText].trim();
                    tooltipBox.style.display = 'block';

                    // Stop propagation to avoid immediate shutdown
                    event.stopPropagation();
                }}
            }}

            // Add interactivity to all diagram elements
            setTimeout(function() {{
                // Get all nodes and interactive elements
                const allNodes = document.querySelectorAll('.node, .cluster');

                // Make each element interactive
                allNodes.forEach(function(node) {{
                    node.style.cursor = 'pointer';
                    node.addEventListener('click', handleNodeClick);
                }});

                // Get specific elements within the diagram
                document.querySelectorAll('g.node text, g.cluster
text').forEach(function(textElement) {{
                    textElement.addEventListener('click', function(e) {{
                        const nodeText = e.target.textContent.trim();
```

```
                    if (descriptions[nodeText]) {{
                        tooltipTitle.textContent = nodeText;
                        tooltipText.textContent = descriptions[nodeText].trim();
                        tooltipBox.style.display = 'block';
                        e.stopPropagation();
                    }}
                }});
            }});
        }}, 1000);

        // Close tooltip when clicking outside nodes
        document.addEventListener('click', function(e) {{
            if (!e.target.closest('.node') && !e.target.closest('.cluster')) {{
                tooltipBox.style.display = 'none';
            }}
        }});

        // Hide scroll indicator after a while
        setTimeout(function() {{
            scrollIndicator.style.display = 'none';
        }}, 8000); // 8 seconds
    }}, 1500);
  }});
</script>
"""

# Render the HTML
components.html(html, height=800, scrolling=True)

# User instructions
st.markdown("""
<div style="background-color: #f0f0f0; padding: 15px; border-radius: 8px; margin-bottom:
20px;">
  <p style="margin: 0; text-align: center;"><strong>Instructions:</strong> Click on any node in
the diagram to see its detailed description.</p>
</div>
""", unsafe_allow_html=True)

# By default, show MC-14 if no selection
if "selected_option" not in st.session_state:
  st.session_state["selected_option"] = "MC-14: Scientific Method"

# Display the title of the selected diagram
st.markdown(f"<h2 style='text-align: center; color:
black;'>{st.session_state['selected_option']}</h2>", unsafe_allow_html=True)

# Render the selected diagram
if st.session_state["selected_option"] == "MC-14: Scientific Method":
  render_mermaid(mc14_diagram, mc14_descriptions)
else:
  render_mermaid(mpdi_diagram, mpdi_descriptions)

# Extra space at the end for tooltips
st.markdown("<div style='height: 300px;'></div>", unsafe_allow_html=True)

# Copyright notice
st.markdown("""
<div style='text-align: center; margin-top: 50px; padding-top: 20px; border-top: 1px solid #ccc;'>
  <p style='color: gray; font-size: 12px;'>© 2025 Ibar Federico Anderson. All rights
reserved.</p>
```

```
</div>
""", unsafe_allow_html=True)
```

Below Python Script (1):

```
import streamlit as st
import streamlit.components.v1 as components

# Configuración inicial de la página
st.set_page_config(page_title="MC-14 y MPDI", layout="wide")

# Información del autor (Texto en blanco)
st.markdown("""
<div style='background-color: #2D2D2D; padding: 20px; border-radius: 10px; margin-bottom: 20px;'>
    <h2 style='color: white;'>👤 Autor</h2>
    <p style='color: white;'>© 2025 <strong>Ibar Federico Anderson, Ph.D., Master, Industrial
Designer</strong></p>
    <div style='display: flex; justify-content: space-between; margin-top: 10px;'>
        <div>
            <p style='color: white;'><img
src="https://upload.wikimedia.org/wikipedia/commons/c/c7/Google_Scholar_logo.svg" style="height: 20px;
vertical-align: middle;"> <a href="https://scholar.google.com/citations?user=mXD4RFUAAAAJ&hl=en"
target="_blank" style='color: white;'>Google Scholar</a></p>
            <p style='color: white;'><img
src="https://upload.wikimedia.org/wikipedia/commons/0/06/ORCID_iD.svg" style="height: 20px; vertical-
align: middle;"> <a href="https://orcid.org/0000-0002-9732-3660" target="_blank" style='color:
white;'>ORCID</a></p>
        </div>
        <div>
            <p style='color: white;'><img
src="https://upload.wikimedia.org/wikipedia/commons/5/5e/ResearchGate_icon_SVG.svg" style="height:
20px; vertical-align: middle;"> <a href="https://www.researchgate.net/profile/Ibar-Anderson"
target="_blank" style='color: white;'>Research Gate</a></p>
            <p style='color: white;'><img
src="https://mirrors.creativecommons.org/presskit/icons/cc.svg" style="height: 20px; vertical-align:
middle;"><img src="https://mirrors.creativecommons.org/presskit/icons/by.svg" style="height: 20px;
vertical-align: middle;"> <a href="https://creativecommons.org/licenses/by/4.0/" target="_blank"
style='color: white;'>CC BY 4.0 License</a></p>
        </div>
    </div>
</div>
""", unsafe_allow_html=True)

# Título de la aplicación con ISO 5807:1985 (Texto en negro)
st.markdown("""
<h1 style='text-align: center; color: black;'>Selecciona una metodología</h1>
<p style='text-align: center; color: black; font-size: 18px;'>Los diagramas de flujo computacionales
(Flowcharts) están basados en la norma <strong>ISO 5807:1985</strong>, que define las convenciones
gráficas para representar procesos lógicos y estructuras de datos.</p>
""", unsafe_allow_html=True)

# Botones personalizados para seleccionar metodología
col1, col2 = st.columns(2)

with col1:
    if st.button("MC-14: Método Científico", key="mc14_button", help="Selecciona esta opción para ver
el flujo del Método Científico"):
        st.session_state["selected_option"] = "MC-14: Método Científico"

with col2:
    if st.button("MPDI: Diseño Industrial", key="mpdi_button", help="Selecciona esta opción para ver el
flujo del Diseño Industrial"):
        st.session_state["selected_option"] = "MPDI: Diseño Industrial"

# Mostrar el diagrama según la selección
if "selected_option" in st.session_state:
    option = st.session_state["selected_option"]

    if option == "MC-14: Método Científico":
        st.subheader("MC-14: Método Científico")
        render_mermaid(mc14_diagram, mc14_descriptions)
    elif option == "MPDI: Diseño Industrial":
        st.subheader("MPDI: Diseño Industrial")
        render_mermaid(mpdi_diagram, mpdi_descriptions)

# Pie de página
st.markdown("---")
st.markdown("Desarrollado por Ibar Federico Anderson © 2025")
```

Below HTML Script (2):

```html
<!-- Información del autor -->
<div style='background-color: #2D2D2D; padding: 20px; border-radius: 10px; margin-bottom: 20px;'>
    <h2 style='color: white;'>👤 Autor</h2>
    <p style='color: white;'>© 2025 <strong>Ibar Federico Anderson, Ph.D., Master, Industrial
Designer</strong></p>
    <div style='display: flex; justify-content: space-between; margin-top: 10px;'>
        <div>
            <p style='color: white;'><img
src="https://upload.wikimedia.org/wikipedia/commons/c/c7/Google_Scholar_logo.svg" style="height: 20px;
vertical-align: middle;"> <a href="https://scholar.google.com/citations?user=mXD4RFUAAAAJ&hl=en"
target="_blank" style='color: white;'>Google Scholar</a></p>
            <p style='color: white;'><img
src="https://upload.wikimedia.org/wikipedia/commons/0/06/ORCID_iD.svg" style="height: 20px; vertical-
align: middle;"> <a href="https://orcid.org/0000-0002-9732-3660" target="_blank" style='color:
white;'>ORCID</a></p>
        </div>
        <div>
            <p style='color: white;'><img
src="https://upload.wikimedia.org/wikipedia/commons/5/5e/ResearchGate_icon_SVG.svg" style="height: 20px;
vertical-align: middle;"> <a href="https://www.researchgate.net/profile/Ibar-Anderson" target="_blank"
style='color: white;'>Research Gate</a></p>
            <p style='color: white;'><img src="https://mirrors.creativecommons.org/presskit/icons/cc.svg"
style="height: 20px; vertical-align: middle;"><img
src="https://mirrors.creativecommons.org/presskit/icons/by.svg" style="height: 20px; vertical-align:
middle;"> <a href="https://creativecommons.org/licenses/by/4.0/" target="_blank" style='color: white;'>CC
BY 4.0 License</a></p>
        </div>
    </div>
</div>

<!-- Título de la aplicación -->
<h1 style='text-align: center; color: black;'>Selecciona una metodología</h1>
<p style='text-align: center; color: black; font-size: 18px;'>Los diagramas de flujo computacionales
(Flowcharts) están basados en la norma <strong>ISO 5807:1985</strong>, que define las convenciones
gráficas para representar procesos lógicos y estructuras de datos.</p>
```

Below is the CSS Code script (3):

```css
/* Estilos generales */
body {
    background-color: #2c3e50;
    color: white;
}
.stApp {
    background-color: #2c3e50;
}
.css-1d391kg {
    background-color: #2c3e50;
}
.stSelectbox label {
    color: white !important;
}
.mermaid {
    background-color: #2c3e50;
}

/* Tooltip */
.tooltip {
    position: fixed;
    background-color: #34495e;
    color: white;
    padding: 30px;
    border-radius: 12px;
    box-shadow: 0 0 20px rgba(0,0,0,0.3);
    z-index: 1000;
    max-width: 600px; /* Más ancho */
    font-size: 22px; /* Fuente más grande */
    line-height: 1.4; /* Espaciado entre líneas */
    pointer-events: none;
    transition: all 0.2s ease;
    border: 2px solid #45566e;
    max-height: 400px; /* Altura máxima */
    overflow-y: auto; /* Scroll vertical si es necesario */
}
```

Below is the JavaScript script (4):

```
// Cargar Mermaid
<script src="https://cdn.jsdelivr.net/npm/mermaid/dist/mermaid.min.js"></script>

// Función para mostrar tooltips
<script>
    function showTooltip(event, title, description) {
        const tooltip = document.createElement('div');
        tooltip.className = 'tooltip';
        tooltip.innerHTML = `
            <div style="background-color: #34495e; color: white; padding: 30px; border-radius: 12px;
font-size: 22px; line-height: 1.4; max-height: 400px; overflow-y: auto;">
                <h3 style="margin: 0 0 15px; font-size: 30px;">${title}</h3>
                <hr style="border: 1px solid white; margin: 15px 0;">
                <p style="margin: 0; font-size: 22px;">${description.trim()}</p>
            </div>`;
        tooltip.style.position = 'fixed';
        tooltip.style.left = (event.pageX + 10) + 'px';
        tooltip.style.top = (event.pageY + 10) + 'px';
        document.body.appendChild(tooltip);
    }

    function hideTooltip() {
        const tooltips = document.querySelectorAll('.tooltip');
        tooltips.forEach(t => t.remove());
    }

    document.addEventListener('DOMContentLoaded', function() {
        setTimeout(() => {
            const nodes = document.querySelectorAll('.node');
            nodes.forEach(node => {
                node.style.cursor = 'pointer';
                const title = node.textContent.trim();
                const description = {descriptions}[title] || '';
                node.addEventListener('click', (e) => {
                    showTooltip(e, title, description);
                });
                node.addEventListener('mouseout', hideTooltip);
            });
        }, 2000);
    });

    // Inicializar Mermaid
    mermaid.initialize({ startOnLoad: true });
</script>
```

Below is a Python flowchart iconographies script with Dracula (Pro):

```
# Diagramas de flujo en Mermaid
mc14_diagram = """
%%{init: {'theme': 'base', 'themeVariables': { 'fontFamily': 'arial', 'fontSize': '16px' }}}%%
flowchart TD
    A([🔍 Observación Curiosa]) --> B[❓ Planteamiento del Problema]
    B --> C[/📚 📖 Revisión de Literatura/]
    C --> D{💡 Hipótesis}
    D -->|Formulación| E[⚗️ 🔬 Diseño Experimental]
    E --> F([📋 Recolección de Datos])
    F --> G[[📈 📊 Análisis de Datos]]
    G --> H{ ✅ Conclusión}
    H -->|👍 Apoya Hipótesis| I[/📂 Redacción del Informe/]
    H -->|👎 ❌ No Apoya| J[[📌 Revisión de Hipótesis]]
    J --> E
    I --> K((👨‍🔬 👥 Revisión por Pares))
    K --> L[(📂 📥 Publicación)]
    L --> M([♻️ Retroalimentación])
    M -->|Nuevas Preguntas| A
    M -->|🏁 Fin del Proceso| N([🏁 Fin])

    classDef default fill:#3498db,stroke:#2980b9,color:white,stroke-width:2px
    classDef round fill:#e74c3c,stroke:#c0392b,color:white,cursor:pointer
    classDef diamond fill:#2ecc71,stroke:#27ae60,color:white,cursor:pointer
    classDef parallel fill:#9b59b6,stroke:#8e44ad,color:white,cursor:pointer
    classDef circle fill:#f1c40f,stroke:#f39c12,color:white,cursor:pointer
    classDef database fill:#1abc9c,stroke:#16a085,color:white,cursor:pointer

    linkStyle default stroke:#ffffff,stroke-width:2px

    class A,F,M,N round
    class D,H diamond
    class G,J parallel
    class K circle
    class L database
"""

mpdi_diagram = """
%%{init: {'theme': 'base', 'themeVariables': { 'fontFamily': 'arial', 'fontSize': '16px' }}}%%
flowchart TD
    A([🏠 Empatizar y Contextualizar]) --> B[/❓ Definir el Problema/]
    B --> C[/👨‍💻 💾 📲 🔗 Investigación Web y DeepSearch/]
    C --> D{💡 ✨ Ideación y Conceptualización}
    D -->|Generación| E[✏️ 📝 🎨 📐 Bocetos, Render 2D y Prototipos 3D]
    E --> F([⚖️ 🔧 Evaluación Técnica])
    F --> G[[⚙️ Iteración y Refinamiento]]
    G --> H{📑 Documentación Técnica}
    H -->|📄 Documentación| I[/👤 Validación con Usuarios/]
    H -->|👎 No Aprobado ❌| J[[▯ Revisión de Diseño]]
    J --> E
    I --> K((_FACTORY 🔬 Producción y Fabricación))
    K --> L[(🚀 Lanzamiento)]
    L --> M([📢 👥 👤 Comunicación y Marketing para Usuarios])
    M -->|Nuevas Mejoras| A
    M -->|🎯 Fin del Proceso| N([🎯 Fin])

    classDef default fill:#3498db,stroke:#2980b9,color:white,stroke-width:2px
    classDef round fill:#e74c3c,stroke:#c0392b,color:white,cursor:pointer
    classDef diamond fill:#2ecc71,stroke:#27ae60,color:white,cursor:pointer
    classDef parallel fill:#9b59b6,stroke:#8e44ad,color:white,cursor:pointer
    classDef circle fill:#f1c40f,stroke:#f39c12,color:white,cursor:pointer
    classDef database fill:#1abc9c,stroke:#16a085,color:white,cursor:pointer

    linkStyle default stroke:#ffffff,stroke-width:2px

    class A,F,M,N round
    class D,H diamond
    class G,J parallel
    class K circle
    class L database
"""
```

Conclusions.

Deploy the Python script to Streamlit Cloud at:https://mc14mpdi-iyltddrgc2nbeiftn44xv5.streamlit.app/

The MC14_MPDI.py script is an interactive web application developed with Streamlit that allows you to visualize and compare two structured methodologies: MC-14 (the 14-stage Scientific Method) and MPDI (Industrial Design Project Methodology), based on the ISO 5807:1985 standard for computational flowcharts. Its main objective is to facilitate the understanding of both processes through interactive graphical representations, integrating detailed descriptions of each stage and dynamic visualization tools.

With an intuitive user interface, initial setup with title, authorship, and academic links (Google Scholar, ORCID, ResearchGate) in a visually appealing format.

Methodology selection via custom buttons ("MC-14" or "MPDI").

Interactive flowcharts. Use Mermaid.js to render diagrams that follow the ISO 5807:1985 standard, with standardized nodes, connectors, and symbols.

Visual elements differentiated by colors and shapes (diamonds for decisions, circles for processes, etc.).

Interactivity via tooltips: Clicking on any node displays a pop-up window with an expanded technical description of the selected stage, extracted from the mc14_descriptions and mpdi_descriptions dictionaries.

The methodologies represented are MC-14: It covers everything from initial observation to publication and scientific feedback, including phases such as literature review, experimental design, and peer validation.

Another methodology presented is: MPDI: Focused on industrial design, with stages such as user empathy, 3D prototyping, technical evaluation and market launch.

Both diagrams allow for iterative cycles (e.g., hypothesis or design review).

Regarding visual customization, built-in CSS styles for tooltips, scrollbars, and animations (e.g., pulsing scroll indicator).

Responsive design with dynamically positioned pop-ups and adaptive content for large screens.

Integration of academic content: links the stages of Design Thinking with the scientific method, as discussed in the document.

Technologies used: Streamlit for the web framework and session state management. Mermaid.js for generating ISO 5807 flowcharts. HTML/CSS/JavaScript for customizing tooltips, animations, and styles. JSON for structuring stage descriptions and linking them to nodes.

The academic purpose of the script serves as a pedagogical tool to visualize complex research processes (MC-14) and industrial design (MPDI) in an accessible way.

Promote methodological transparency, aligning with international standards.

Facilitate critical comparison between scientific and practical approaches, as discussed in the attached document on Design Thinking and R&D&I.

In short, the script combines academic rigor, technical standards, and user-centered design to democratize access to structured methodologies, reflecting the intersection of science, design, and innovation proposed in the accompanying research.

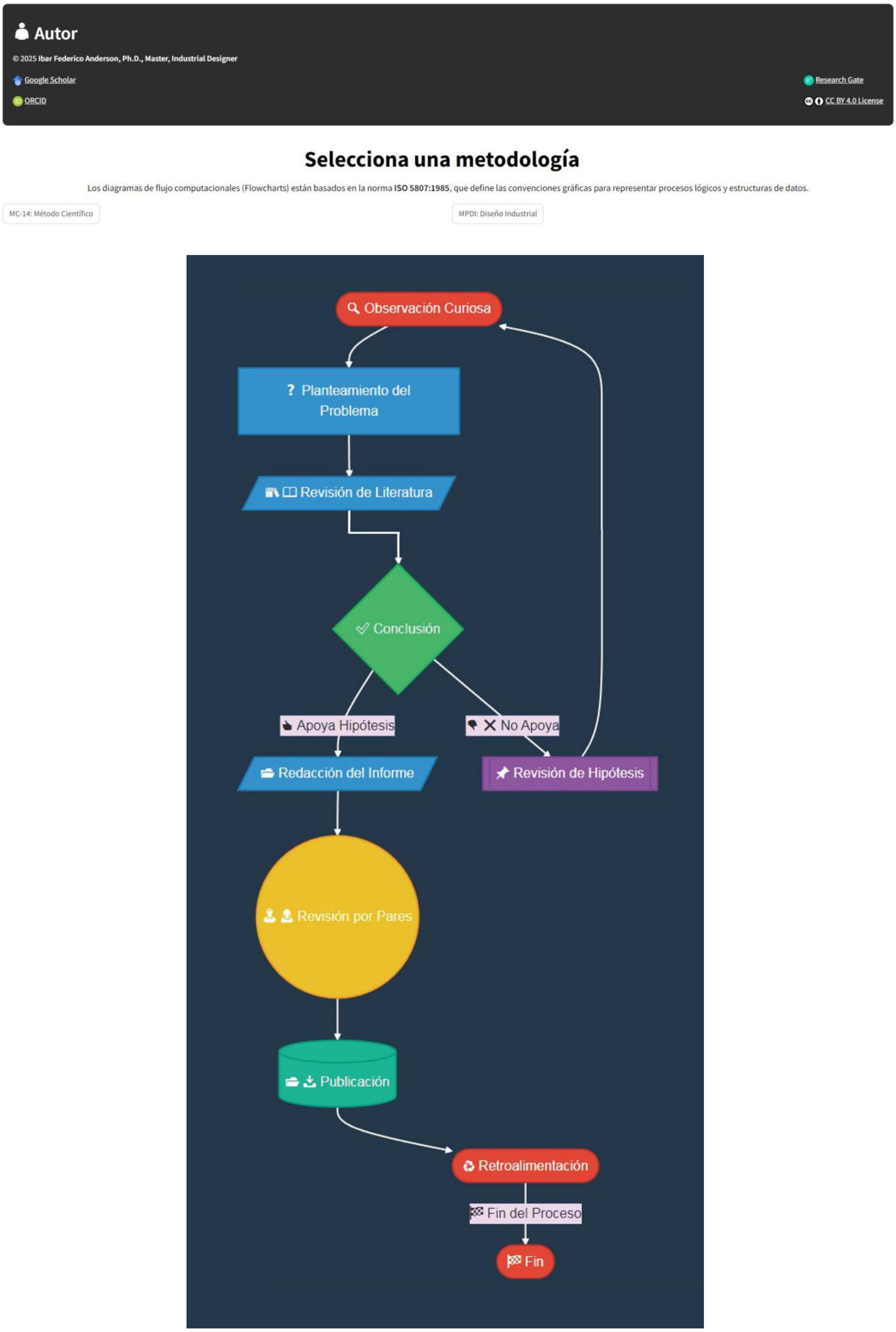


Figure 25. ISO 5807: 1985. Flowcharts: MC-14.

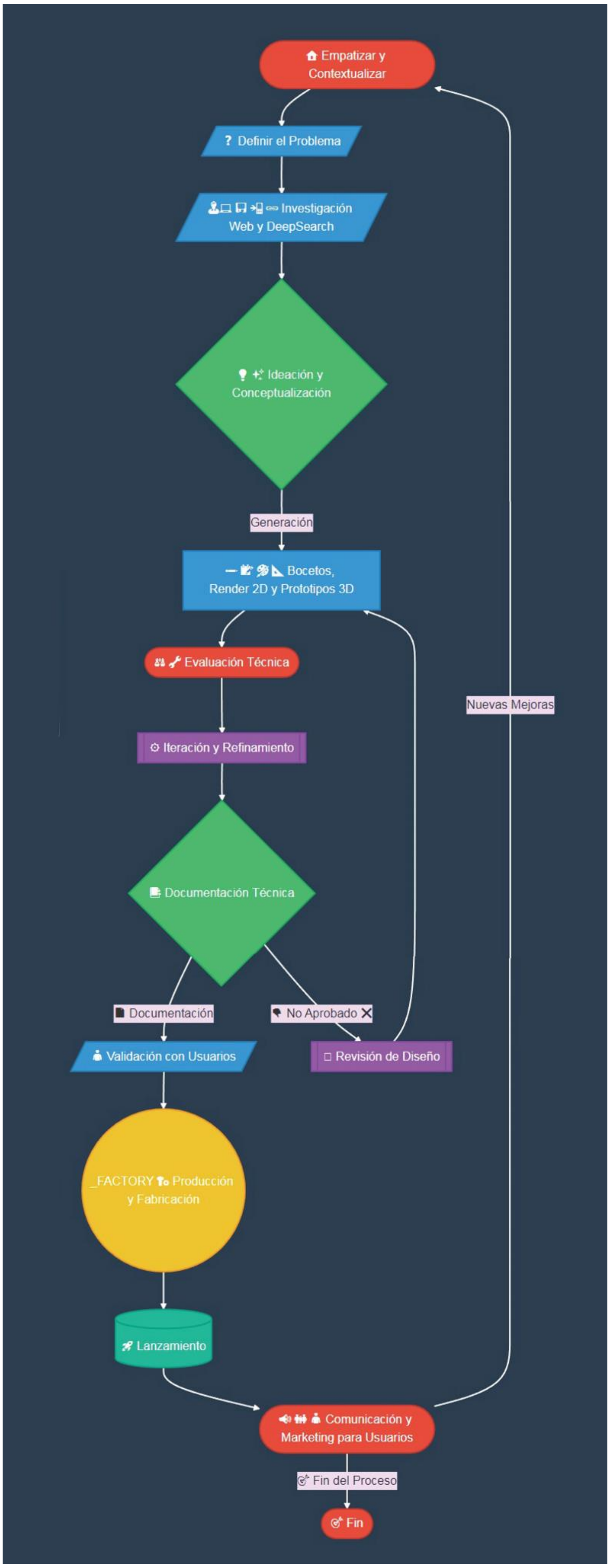


Figure 26. ISO 5807: 1985. Flowcharts: MPDI.

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