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Scientific methods of Leonardo da Vinci's prototypes. An experimental approach on sustainable product design

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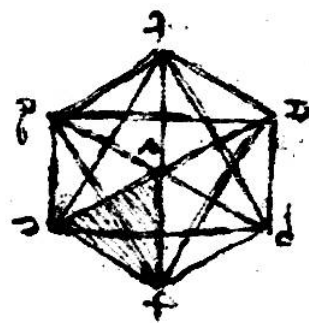
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THE vast legacy left by Leonardo da Vinci to the heritage of humanity stands as undeniable proof that a creative, curious spirit, driven by an unrelenting desire for innovation, knows no boundaries when it comes to exploring the world around us. In his time, Leonardo pushed the limits of Renaissance society, leveraging the scarce resources and knowledge available to him to pioneer ideas and designs that still inspire generations. Today, in a world where technological advancements far surpass the tools of Leonardo's era, we find ourselves in a unique position to make extraordinary experimental leaps. The conditions of our time invite us to embrace the same spirit of curiosity and innovation that defined Leonardo's work, but with capabilities that allow us to explore, create, and transform in ways he could only dream of. Drawing inspiration from the Renaissance master, it reflects on how the principles of creativity and exploration can be applied to current challenges, pushing the boundaries of knowledge and innovation in unprecedented ways.

This article explores the enduring relevance of Leonardo da Vinci's visionary thinking within the framework of contemporary design education, particularly in relation to sustainability and experimental methodologies. Leonardo's legacy—as an inventor, observer of nature, and integrative thinker—offers more than historical fascination; it provides a profound conceptual model for addressing present-day design challenges. His cognitive processes, visual reasoning, and ability to merge science, art, and technology anticipate many of the principles that now define sustainable design: functionality, resource efficiency, and harmony with the natural world. The study situates Leonardo's unfinished works and inventive prototypes as generative tools for reflection and creation in the

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academic environment. Through a pedagogical experiment developed within a university design studio, students engaged with concepts such as incompleteness, adaptive reuse, and circularity, transforming absence and dysfunction into opportunities for innovation. By adopting a methodological framework inspired by Leonardo's own approach—combining phenomenological experience, epistemological inquiry, and semiotic awareness—the research fosters a holistic understanding of sustainability that transcends technical performance.

Leonardo's fascination with the unfinished and its potential reflects a mindset that challenges the limitations of human understanding and creativity. By revisiting his innovative approach, this experiment sought to reinterpret his unfinished concepts, adapting them to contemporary contexts while respecting their original intent. The exploration of the “incomplete” in Leonardo da Vinci's work served as the central theme and inspiration for this educational experiment. Both at the urban scale and the object scale, the project aimed to delve into the boundaries that the Renaissance inventor sought to surpass. However, these boundaries were examined through diverse lenses, sometimes subjective and deeply personal, other times rational and grounded in scientific reasoning. In revisiting Leonardo not merely as a historical figure but as a precursor to today's designer, this article bridges past and present, proposing that his model of inquiry remains deeply relevant for educating a new generation of creators capable of navigating complexity with responsibility, creativity, and vision.

Methodology. Leonardo Da Vinci's prototypes, the subject of a didactic process

When discussing the process of composing an object or project, Leonardo uses an analytical method similar to deconstructivism. Each of the determining phases is analyzed separately, looking for the best ways to integrate them into a unitary approach. If we were to describe this process succinctly, we can refer to understanding the component elements, the problem underlying the need for intervention, investigating how a new system or mechanism can provide an answer, carrying out experimental applications to test the design solution, returning to the itinerant process of analysis. Such partial or total decomposition and recomposition of the working method will constantly generate new conclusions on the strategic impact of the invention in response to a real situation. More often than not, Da Vinci's questions about objects' general functioning led to innovation and experimentation.

In the interior architecture workshop, such a deconstructivist process set out to highlight all those dysfunctions and shortcomings is found both in the city and in object design. The “incompleteness” often appeared in the case study methodology. This was first of all defined as a form to be analyzed and (re)structured to identify how it can be integrated into a wider context, i.e., cosmetized or healed, to be reused to respond to current needs. On the other hand, ‘incompleteness’ translates as a state of crisis and uncertainty associated with the object, which leads to experimentation and innovation. The lack of articulating elements, strategically linking pieces of the urban fabric or components of a design object, leads to a systemic interpretation of the intervention. All conceptual approaches pursue new methods of abstraction

and synthesis, often inspired by fields related to architecture: natural sciences, mathematics, astronomy, physics, etc.

In order to construct a narrative project, starting from the scientific meaning attributed to Leonardo's ideas, we have resorted to the in-depth analysis and decoding of various works on urban planning, building architecture, as well as the structures and mechanisms proposed by the master. This process started with the sketch, the prototype and went as far as the decomposition of the systems to determine the central element, the generator, which contributes to the activation and functioning of the whole. Subsequently, each student investigated an issue, encountered in everyday life and defined by the notion of "incompleteness", such as: perished areas of the contemporary city, dysfunctions related to circulation and spatial crossing, urban island junctions and links through suspension or floating bridges, abandoned buildings, functional voids or objects that are destroyed, damaged or out of use. All these situations have fostered changes, improvements and the transformation of impediments into opportunities. With Leonardo as an inspiration for new projects, we have resorted to the introduction of systems found in the ideal city, mobile mechanisms, the hierarchization of circulation, spatial uses or the imagining of new transport solutions.

The aim of this design research was first and foremost to provide a solid argumentative and scientific basis for any new design concept. This approach pre-empted situations in which the architectural solution is limited

to arbitrary, formal, aesthetic results that are not aimed at responding to the direct needs of the user. Architecture remains a project for and about people.

This thematic approach provided students with a platform to investigate the intersections of personal interpretation and scientific inquiry. It highlights how engaging with Leonardo's incomplete works offers a profound understanding of the processes that drive innovation and a renewed appreciation for the enduring relevance of his ideas in modern design and research methodologies.

Pioneering Sustainability through Leonardo's Design Thinking

"His name becomes so renowned that not only is he esteemed during his lifetime, but his reputation endures and even grows after his death."

(Giorgio Vasari about Leonardo da Vinci)

From a historical design perspective, Leonardo da Vinci is frequently positioned as a precursor to the modern designer,¹ being recognized as a true generator of solutions that articulate—through a visionary approach for his time—a remarkable synthesis between science, art, and technology. Through thousands of technical sketches compiled in codices—today dispersed across France, Italy, Spain, and the United Kingdom—Leonardo leaves behind a visual legacy that reconstructs only about a quarter of his extensive body of work.² These sketches do not necessarily reflect built constructs, but rather unveil a profound cognitive process oriented toward ex-

¹ Bürdek, Bernhard E., *Design: History, Theory and Practice of Product Design*, Berlin-München-Boston: Birkhäuser, 2015, p. II.

² Elletti, Valerio, Cianchi, Marco, Bertolotti, Albino, Pedretti, Carlo, *Leonardo i codici*, Firenze: Giunti, 1995.

ploration, modeling, and systematization. In the absence of conclusive evidence regarding the realization of many of these projects, it is reasonable to assert that a significant number remain in the stage of conceptual or preliminary design³—a characteristic that today offers an extended framework for interpreting Leonardo’s design approach, with an emphasis on the creative process itself, rather than its material outcome.

The extensive and methodically structured nature of Leonardo da Vinci’s visual documentation offers profound insight into his cognitive framework and, more significantly, into the way he conceptualizes the design process. This remarkable clarity of visual thinking establishes a compelling parallel with the contemporary practice of industrial design. Leonardo approaches each project as an integrated process—beginning with empirical observation, followed by functional analysis, the definition of objectives, the generation and visualization of solutions, and, whenever feasible, their empirical validation through testing.

A clear illustration of Leonardo’s intuition regarding the future role of the designer is found in his letter of intent to Ludovico Sforza, Duke of Milan. In this document, he presents not only his engineering skills—from the construction of bridges and defense systems to the design of siege machines—but also his architectural and artistic competencies, citing his capacity to produce works of

painting and sculpture. This fusion of technical utility and aesthetic expressiveness outlines a deeply holistic vision, in which functionality and beauty are inseparably linked, anticipating how Cross would later define design as a third culture.⁴ Leonardo is aware of the complex nature of his vision, marked by visual synthesis and systematization—essential traits of the contemporary designer.⁵ In this sense, Leonardo anticipates what is now theoretically acknowledged: design stands at the intersection of science and art, mediating between logic, technology, expression, and culture.⁶

A defining concept in Leonardo da Vinci’s thinking is what today may be termed the principle of natural efficiency—the conviction that nature produces nothing unnecessary or excessive, but instead operates according to intrinsic criteria of optimization.⁷ This principle, explicitly formulated in Leonardo’s notes, reflects the idea that each element within a natural system has a clearly defined and functionally justified role. Thus, Leonardo anticipates modern design principles such as *form follows function*, foreseeing the functionalist thinking that would dominate industrial design centuries later. Moreover, his approach reveals one of the earliest forms of sustainability consciousness. For Leonardo, nature is the ideal model of balance, simplicity, and efficiency—values that serve as reference points for any human creative intervention. His assertion—“Invention

³ Cianchi, Marco, Burmeister, Joachim, Pedretti, Carlo, Vezzosi, Alessandro, *Le macchine di Leonardo*, Firenze: Becucci Editore, 1984.

⁴ Cross, Nigel, *Designerly ways of knowing*. London: Springer, 2006, pp. 1–4.

⁵ Capra, Fritjof, *Learning from Leonardo: Decoding the notebooks of a genius*. San Francisco: Berrett-Koehler Publishers, 2013, p. 157.

⁶ Cross, 2006, p. 100.

⁷ Cerveró-Meliá, Ernesto, Capuz-Rizo, Salvador F. and Ferrer-Gisbert, Pablo, “Leonardo da Vinci’s contributions from a design perspective.” *Designs*, 4 (2020), p. 38.

will never be more beautiful, more simple or more to the purpose than Nature's"⁸—directly underscores this vision. In this regard, his thinking aligns remarkably well with the foundational principles of contemporary sustainable design, in which resource economy, functionality, and harmonious integration within ecosystems are essential criteria of the design process.

Leonardo da Vinci may be regarded as a pioneer of biophilic design,⁹ grounding many of his inventions in the systematic observation of nature. His studies of bird flight inform early aeronautical concepts, while anatomical analyses of humans and animals underpin mechanisms that anticipate biomechanical principles. For Leonardo, engineering is not only a pursuit of efficiency, but also a means of maintaining harmony with the natural environment. His work thus exemplifies an early form of nature-inspired design aimed at reestablishing a connection between humans and their ecosystem. Notably, despite his profound anatomical knowledge, Leonardo does not position himself as a physician; his inquiry into natural systems stems not from a desire to intervene medically, but from an intent to replicate their inherent efficiency for design purposes.

The ideas related to circularity have emerged as foundational principles in contemporary design, particularly in architecture and the arts, where they are increasingly associated with sustainable thinking and systemic inte-

gration. However, this principle is far from novel. It finds conceptual precedent in the works of historical figures such as Leonardo da Vinci, whose profound understanding of geometry and proportion is evident across his artistic compositions and architectural designs. The circular and spiral forms—frequent in his studies and inventions, including the iconic spiral staircases—reflect not only formal elegance but also biomimetic inspiration, often believed to be modelled after natural structures like marine gastropod shells.¹⁰ Contemporary architectural education, especially within the Florentine tradition shaped by Leonardo Ricci and Leonardo Savioli, continues to draw upon these Renaissance principles. Their pedagogical emphasis on merging intellectual creativity with social responsibility echoes da Vinci's ambition to unify scientific inquiry with artistic expression. This integrated design ethos reinforces the notion that form and function must serve both aesthetic and societal purposes.¹¹

Leonardo's innovative mindset is equally evident in his exploration of automated systems. Recent studies on the automation of his machines illustrate a lineage that links his mechanical imagination to current applications in automation and circular design strategies—where motion, return, and renewal form the core operational logics.¹²

Moreover, the mathematical precision underpinning Leonardo's design process serves as a precursor to modern design thinking

⁸ Cerveró-Meliá et al., 2020, p. 38.

⁹ Benyus, Janine, *Biomimicry: Innovation inspired by nature*. New York: Harper Perennial, 2009. pp. 2–8.

¹⁰ Annesley, Thomas M, "Clinical Chemistry." *Da Vinci's spirals and their influences on modern architecture*, 63/4 (2017), pp. 931–933.

¹¹ Pedrabissi, Dario. "Contemporary architectural education and the radical experiments in 1960s in Florence." *Advanced Materials Research* (2013), pp. 671–674, 2180–2185.

¹² Bucolo, Maide, Buscarino, Arturo, Famoso, Carlo, Fortuna, Luigi and Gagliano, Salvina "Automation of the Leonardo da Vinci machines." *Machines*, 8 (2020), p. 53.



Fig. 1 – Preliminary research sketch by student Maria Vătășelu. Supervising professors: Bogdan M. Ioniță, Maria Popa, Alexandra Dunel, Iulia Ștefănescu. University of Architecture and Urbanism “Ion Mincu” (UAUIM)

frameworks, particularly those employed in interdisciplinary urban mobility projects focused on ecological responsibility and circular economy principles.¹³ His capacity to synthesize mathematical rigor with artistic vision reveals a holistic approach to design that remains profoundly relevant. As Bento argues, such integration exemplifies the Renaissance ideal of interconnected knowledge systems—art, science, and philosophy converging toward innovation.¹⁴

In this light, interpreting the notion of circularity through Leonardo’s work not only enhances our understanding of sustainable design but also reinforces the enduring value of his legacy. It highlights a design culture where beauty, efficiency, and ecological awareness are inseparable, providing a timeless model for innovation in both architectural education and practice.

¹³ Viviani, Sara, Gulino, Michelangelo-Santo, Rinaldi, Alessandra and Vangi, Dario, “An interdisciplinary double-diamond design thinking model for urban transport product innovation.” *Energies*, 17 (23), 5918 (2024).

¹⁴ Bento, Sílvia, “Arte, ciência e filosofia na Renascença Italiana: Em torno das teorias da arte de Leon Battista Alberti e de Leonardo da Vinci.” In *Filosofia: Revista Da Faculdade De Letras Da Universidade Do Porto*, 2014.

From Codex to Concept: Leonardo's Approach Reflected in a University Product Design Project

Leonardo da Vinci's design methodology, though rooted in the Renaissance, reveals a structural logic strikingly aligned with contemporary product design practices. This parallel becomes evident when comparing the stages he follows—rigorous observation, functional analysis, solution generation, graphic representation, and experimentation—with those employed in today's academic design education. To illustrate this continuity, the present study examines a third-year, first-semester chair design project from the “Ion Mincu” University of Architecture and Urbanism (UAUIM), Product Design program, considered a foundational exercise in cultivating project-based thinking.

The project reflects Leonardo's holistic design approach, structured around three distinct yet interrelated methodologies: phenomenological analysis, epistemological investigation, and semiotic interpretation. Students engage with these dimensions through a range of tools, from observational sketching and diagramming to 3D modeling and physical prototyping. The design process becomes a systematic exercise in critical thinking, where detailed analysis, functional synthesis, and integration of natural principles converge to produce coherent, efficient, and sustainable outcomes. Design, in this context, is not reduced to formal aesthetics, but is treated as a sequence of iterative reflections, experiments, and informed decisions responding to contemporary challenges. The methodology follows two key phases.

The first involves a critical analysis of an existing chair, focusing on morphology, structure, functionality, and ergonomics, complemented by a sustainability assessment, considering materials, manufacturing processes, and durability. This phase mirrors Leonardo's method of beginning with the observation of existing systems, rather than a blank slate, to explore the relationship between form and function.

The second phase consists in the development of an original design proposal, derived from insights gathered in the analysis. The outcome must meet ergonomic and structural criteria while incorporating sustainability goals such as the use of renewable materials, resource efficiency, and life cycle extension. The project is presented through a comprehensive portfolio including concept boards, formal explorations, 3D models, prototypes, and a reasoned justification of design choices.

a) The Phenomenological Dimension: Experience as a Source of Form

In applying this method, the project encourages the student's immersion in a direct, personal, and perceptual relationship with the studied object. The existing chair—the starting point of the entire endeavor—is not initially approached from a formal or constructive perspective but is explored through the lens of atmospheric experience.¹⁵ Emphasis is placed on presence, user gestures, memory, and the emotional states elicited by unmediated interaction with the object.

This phenomenological relationship suspends the impulse for immediate intervention, favoring reflective immersion, which enables the subtle recording of the object's

¹⁵ Zumthor, Peter, *Atmospheres: Architectural environments, surrounding objects*. Basel: Birkhäuser, 2006, pp. 7–13.

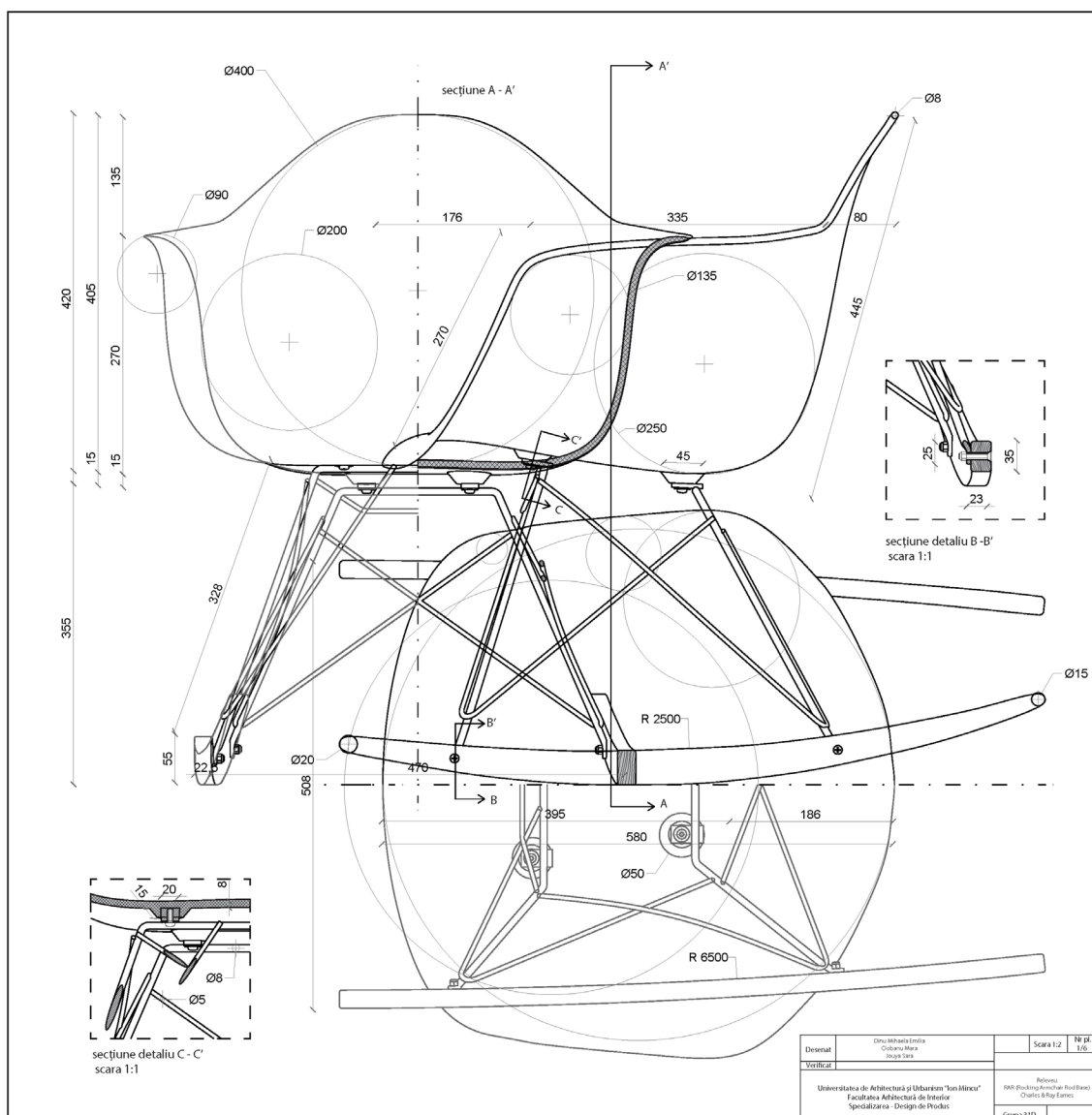


Fig. 2 - Technical drawing based on direct observation and measurements taken from the real-life object. Design students: Mihaela Dinu, Mara Ciobanu, Sara Jouya. Supervising professors: Bogdan M. Ioniță, Maria Popa, Alexandra Dunel, Iulia Ștefănescu

character, its spatial expression, and the way it conditions human behavior. The student is encouraged to observe and render these dimensions through sketches, drawings, and expressive representations, which become a form of visual translation of lived experiences and perceptions. In this context, form is not conceived as an abstract construct, but as an emergent quality of direct experience.

Much like Leonardo, who begins with profound observation to extract the functional essence of phenomena, the student is guided to understand and interpret form as the result of a sensitive and meaningful relationship with the analyzed object.

b) The Epistemological Dimension: Design as a Process of Knowledge

Within the epistemological method, design is approached as a progressive process of acquiring and validating knowledge. In Leonardo da Vinci's case, this dimension manifests through the application of an early scientific logic: systematic observation, hypothesis testing, deductive reasoning, and critical reevaluation of conclusions. His statement

First I shall test by experiment before I proceed further, because my intention is to consult experience first and then with reasoning show why such experience is bound to operate in such a way. And this is the true rule by which those who analyse the effects of nature must proceed: and although nature begins with the cause and ends with the experience, we must follow the opposite course, namely, begin with the experience, and by means of it investigate the cause.¹⁶

highlights the inductive nature of his method, where design becomes an instrument for understanding how the world functions. A relevant example of this aspect is Leonardo's study of blood circulation, which, through hydraulic analogies, demonstrates how careful observation of natural phenomena can inform the development of reproducible mechanical models. (Fig. 1)

In the context of the chair project, the epistemological method is applied through a sequence of stages involving documentary research, direct observation, formulation of usage hypotheses, model development, ergonomic-functional testing, and continuous review of proposed solutions. Prototyping thus



Fig. 3 – Final project visualization developed following the research phase. The design features an ergonomically adaptive chair based on a central spring mechanism. Design students: Mihaela Dinu, Mara Ciobanu, Sara Jouya. Supervising professors: Bogdan M. Ioniță, Maria Popa, Alexandra Dunel, Iulia Ștefănescu

becomes not merely a technical phase, but an active medium for reflection and adjustment. Students are guided to express these observations and conclusions through tools specific to product design communication: the measured drawing of the analyzed object serves as the starting point, followed by the study of ergonomics, functionality, and materiality. (Fig. 2) Within this framework, the issue of material sustainability is frequently subjected to critical reexamination, as the studied objects may originate from periods in which ecological considerations were absent. This tension highlights the rupture between the design thinking of previous eras and the contemporary principles inspired by Leonardo's model,

¹⁶ Pasipoularides, Ares, "Historical continuity in the methodology of modern medical science: Leonardo leads the way." *International Journal of Cardiology*, 171/ 2 (2014), pp. 103–115.

where form, function, and ecological responsibility are inextricably connected.

c) The Semiotic Dimension: The Object as a Carrier of Meaning

Leonardo da Vinci masterfully utilizes visual communication, employing drawings, exploded diagrams, and annotated sketches not merely as technical representations, but as authentic forms of graphic language. Each visual element serves a clear purpose in transmitting concepts, functional analogies, and logical structures. From a semiotic perspective, these representations may be interpreted as systems of signs, where form is inseparably linked to meaning.

The final method identified in Leonardo's design structure directly addresses this semantic charge of form. Despite being active during the Renaissance, his designed objects do not replicate any stylistic code typical of the era. Instead, his approach generates a timeless visual language in which meaning derives directly from function rather than ornamentation. This pure semiotics grants his objects an essentialized, functional aesthetic, permanently open to reinterpretation by each generation. In contemporary design, objects such as chairs transcend their purely functional role, becoming carriers of cultural, social, and stylistic identity. Each historical period loads form with its own symbolic content—ranging from ornament to proportion and materiality—expressing the *zeitgeist*. Much like Leonardo, today's designers build visual narratives through the form of objects, articulating intentions and values in the language of material expression. For students, this dimension materializes in the final stage of the project, which in-

volves reinterpreting the studied chair into a personal and sustainable design vision. The object thus becomes a synthesis of functionality, expressiveness, and message. The resulting concept reflects a new interpretive framework anchored in current values, upon which the principle of sustainability is superimposed, conferring upon the chair an atemporal aesthetic and symbolic relevance aligned with the present. (Fig. 3)

From Codex to Urban Canvas: Temporal Layers and the Rewriting of City Spaces

One relevant aspect of Leonardo da Vinci's study is the interpretation of the relationship between representation and technique (*Tekhne*), as theorized in Aristotle's *Metaphysics*. Rediscovering the essence of things and being is a recurring theme in the Renaissance period. According to the Greek philosopher, Leonardo also approached the theme of forms in close connection with the sensory process. These forms draw inspiration from the living world, but they possess the capacity to transform themselves, metamorphosing into mechanisms that belong exclusively to technique. This constant mobility of any system constitutes a dialectical approach to the principles that comprise matter.

Each form is considered unique and belongs to an entity. This lack of generalization translates into a systemic approach to the surrounding reality. From the Codex Urbinas Latinus 1270, we learn how important drawing is for Leonardo as an expression of form, which is 'more infinite' in interpretation than nature itself.¹⁷ In a semiotic

¹⁷ Da Vinci, Leonardo, *Treatise on Painting (Codex Urbinas Latinus 1270)*, translated and annotated by A. Philip Mc-



Fig. 4 - Final project visualization developed during the interior design studio for Curtea Veche ensemble in Bucharest. Interior Arch. student: Mihai Popa. Supervising professors: Oana Diaconescu, Daniel Armenciu, Astrid Rottman, Ruth-Adalgiza Iacob

discourse, we could conclude the dialectical relationship between the opposites in the artist's architectural works: the nature of the ideational and that of pure reality; that is to say, the figure-ground relationship, which often transcends the signified.

By correspondence, Ricoeur draws his principles from the works of Plato.¹⁸ The structure of man and his history depend on the narrativity of discourse, which provides the framework for the hermeneutical correspondence between interpretation and symbol.

In Plato's *Dialogues* the misunderstanding of memory arises because of the connection between the image (*eikon*) and the metaphor of imprinting (*typos*), associated with the distinction between the reality of movement and the reality of spatial imprinting. Aristotle, on the other hand, defines representation as the direct consequence of learned experience and considers it the result of the superimposition of all types of memory. In architecture, the event, as outlined by phenomenologists such as Jan Patocka,¹⁹

Mahon, 2 vols. Princeton: Princeton University Press, 1956, p. 35.

¹⁸ Wahlberg, Malin, *Documentary time*. Minneapolis: University of Minnesota Press, 2008, p. 141.

¹⁹ Mihali, Ciprian, *Inventarea spațiului*, București: Editura Paideia, 2001, pp. 60-113.



Fig. 5 - Final project visualization developed during the interior design studio for the city centre of Bucharest. Interior Arch. students: Larisa Călin, Crina Ciurea, Bianca Manea. Supervising professors: Oana Diaconescu, Daniel Armenciu, Astrid Rottman, Ruth-Adalgiza Iacob

is determined solely through processes of stratification, whereby what has been erased is decanted from what is preserved, with the aim of imprinting the image through memory. Such an analytic and perceptive image relies on the ability to narrate the approach of spatial comprehension and chronology, in a study that depends on a correct understanding of the index.

Most projects developed in the design stu-

dio dedicated to interior architecture followed these principles: multidisciplinary, duality of anthropomorphism and geomorphism, functional stratification, the system city, interpretation of the ornithopter, introspection, (de)codification, and relationships within the social context, related to a continuous evolutionary process inherent to human nature.

Movement is understood in direct relation

to the human being. This theory can also be supported by Aristotle's example concerning the origin of this process. In the case of building, for instance, movement is expressed through the very art of construction, with the aim of creating a shelter, while matter is represented by "earth and stones, and form is the plane".²⁰ In the representation of form, mobility is integrated through both associations and decompositions. This was the interpretation of the Stirbei Palace in Bucharest, situated on one of the city's oldest commercial arteries, Calea Victoriei. A historic edifice built in 1835 by Barbu Dimitrie Stirbei and designed by the French architect Michel Sanjouand, it has endured a tumultuous history with numerous restorations and reuses, not always the most fortunate. The imposing interior garden leaves a lasting impression. A new life is thus taking shape within this dark, enclosed, isolated space, akin to the fetus studied and represented by Leonardo Da Vinci. The connections between these disused or unused inner courtyards behind the buildings are a characteristic feature of Bucharest, defined by a densified and constantly expanding urban fabric, creating a network of gardens and pedestrian green spaces. Consequently, the landscape is altered, varying from its original natural forms to semi-natural, agricultural, and artificial ones, in a cyclical process in which man and nature claim dominance. In the Roman period, the site indicated that vegetation is 'constructed' and can be reinterpreted today. The Hellenistic civilization was founded on an image of organic nature, so the intention to estab-

lish univocal botanical criteria in the design will have to be eliminated, considering each analysis as particular.

The North Railway Station in Bucharest adopts a unique approach, merging historical significance with architectural innovation, revitalized by the integration of a futuristic building. Inspired by Leonardo da Vinci's vision of the vertical city, it features functionally layered spaces enriched with urban greenery and defined by strong community ties. This organic structure encompasses a central spiral of terraced greenery that embodies contemporary sustainable principles. The ideal city is envisioned as a functional hub, where movement is clearly defined and fluid, and human interaction is encouraged through open, walkable areas and intelligent structures.

Roland Barthes, in his *Rhetoric of the Image*, interprets the imprint of a sign as a form of extra-textual perception.²¹ The narrative takes shape *a priori* around the concept of trace. The time of Leonardo's imagined architectures is to be read in relation to the temporal overlap between the present moment and the context of the Renaissance period. By breaking down the images proposed by the artist into clearly defined planes, the traces emerge as fragmentary signs inseparable from the original context. The canals and nature, for example, although contextualized, play a central role, immortalizing the event and generating a series of meanings typical of today's dynamics. On the other hand, it is the buildings that introduce a trace through a spatio-temporal reading. The deciphering of each layer reveals all the areas

²⁰ Aristotle, *Metaphysics*, Trans. by W. D. Ross, Cambridge, MA: Harvard University Press, 1953, p. 117.

²¹ Barthes, Roland, "Rhetoric of the Image, Image-Music-Text", trans. Stephen Heath, New York: Hill and Wang, 1977, pp. 32-51

of discontinuity in the reading of the whole. In the proposal of Curtea Veche, which serves as another example of the valorization of vestiges, this time pertaining to the main archaeological nucleus of Bucharest, we can specify that the reading of each element of the site reveals a series of characteristics or indices. Based on these, a temporal relationship is developed between the elements of the system that have vanished from the visual frame but whose action classifies the representation (Fig. 4). This technique can be associated with the architectural project as presented by Leonardo, because, like the archaeological frame or semiotic discourse, it is possible to create a true image of the entire field of perceived representation.

One of the project solutions aims to reconnect the fragmented urban fabric of the Dâmbovița riverbed and organize recreational spaces for the Bucharest community through a series of fixed and movable bridges. To develop the proposal, the students analyzed the Bosphorus Bridge (Ms. L, cc. 65v-66r), the self-supported bridge (Codex Atlanticus, c. 71v [23v-a]), and the rotating bridge (Codex Atlanticus, c. 855r [312r-a]) as floating elements that can be displaced along the river for strategic purposes. To facilitate transportation along the river, Leonardo's proposals for mitred-gate locks were utilized, enhancing mobility efficiency (Codex Atlanticus, c. 28r [7v-b]). The bridges, with their removable and transformative capacity, can be considered mechanisms within the city system.

As represented in Nolli's plan, configuring Enlightenment Rome through an image of the form-bottom relationship, alternations would be introduced into a homogeneous fabric, similar to the project in the historic Lipsani area of Bucharest (Fig. 5). Returning to Leonardo's ideal city, we can add new

attributes such as order, balance, proportion, and symmetry, based on a rigorously expressed geometry; attention to functionality aspects, efficient use of spaces, accessibility, and circulation facilities through the use of cryptoporticus involving underground connections (tunnels) linking different areas; a social hierarchy of areas reflected in the arrangement of public space on the ground floor and basement, and private space on the upper levels; as well as aesthetics and symbolism combined with a flexible spatial organization. The Curtea Veche in Bucharest faces significant challenges due to the partial destruction of architectural elements, limited accessibility for individuals with reduced mobility, and difficulties orienting in the fragmented space. An effective solution could be the creation of a partially covered pedestrian walkway on French Street, inspired by Leonardo da Vinci's vision of urban organization and his preference for porticoes. This passage would bridge the elevation differences between Șelari and Căldărari Streets, enhancing access and orientation toward the Curtea Veche. The walkway would also include informational areas concerning the historical heritage of the central area. In contrast to the surrounding buildings, the walkway will highlight the remains, while its subordinate design will enhance the historic site, thus underscoring its cultural and architectural significance.

In Leonardo's city system, all entities communicate directly, and the formal balance created can be linked to the integration of logic, aesthetics, and symbolism, influenced by an anthropological perspective. This symbiosis between context and architectural intervention translates into camouflage, a process driven by the building's ability to blend with its surroundings through its form and "dialogic" materials, effectively erasing

their contours.²² Additionally, it reflects the imitation of a building's image that is foreign to its context, characteristic of an unconventional system of messages, concepts, and configurations. In specific cases, what remains of the original building is a substance differing in size and shape from its predecessor— a remnant of what once existed. The image of an abandoned building within the city can serve as the central argument for the intervention. Leonardo employs a unique visual rhetoric, marked by analytical decompositions and original articulations between spaces, which is considered an innovation concerning forms and the narrative discourse among them.

Conclusions

Regarding the methodology of the design process, regardless of its destination, Leonardo's main source of inspiration is nature. His sketches are a testament to his countless attempts to understand natural phenomena, principles of the functioning of matter as well as strictly formal aspects. Today, all these sources represent specific methods of biophilic design, a branch of design that discusses the recovery of principles existing in nature to solve current design problems. In this sense, Leonardo interprets the mechanism as a link between form and function, bringing back a current concept in design by referring to the user/human as the main design objective. This principle was approached through human centred design, thus becoming an important vector through which Leonardo's inventions can be approached in product design workshops, providing a valuable case study.

Leonardo daVinci's works, often conceived as experimental prototypes, reflect the boundless curiosity that defined his personality. By studying his legacy, we can observe various stages in the evolution of his research. Some concepts remained as initial sketches of ideas, while others materialized as objects designed to test fundamental principles of physics. Analyzing the diversity of these prototypes from a contemporary perspective reveals their alignment with what we now consider a sustainable approach. Creating objects that address specific needs with minimal effort and maximum impact epitomizes the ideal of sustainable design.

In this sense, Leonardo's design principles take shape in creative forms that aim to reduce environmental impact. His materials were predominantly natural and easy to manipulate, underscoring a resourceful and efficient methodology. Today, driven by the desire to extend the life cycle of products, we employ various strategies for recovery, recycling, and reuse. These practices often lead to transforming waste or residual materials into innovative products with unique properties. Under the umbrella of life cycle thinking (from cradle to cradle), everything we create today holds the potential to take on a new form in the future or reintegrate seamlessly into the environment with minimal impact. This approach emphasizes the importance of designing objects and systems that not only meet immediate needs but also consider their long-term impact on the planet.

By adopting this perspective, designers and architects can ensure that materials and products are part of a continuous regenerative cycle, where waste is minimized, and resources are reused. This philosophy encourages in-

²² Behrens, Roy R., *False colors: Art, design and modern camouflage*. Dysart, IA: Bobolink Books, 2002, pp. 19-27.

novation in material science, manufacturing processes, and design strategies, paving the way for sustainable solutions that align with the principles of environmental harmony and resource efficiency.

In the context of academic experiences, these principles have been explored by creating objects rooted in sustainability. Drawing inspiration from Leonardo's experimental ethos, students designed and produced items that integrate recycled and repurposed materials, demonstrating how historical approaches to resourcefulness can inform and enrich contemporary practices. This exercise highlights the enduring relevance of Leonardo's methods, bridging the gap between past ingenuity and modern sustainable design.

This expanded exploration examines how Leonardo's legacy can inform innovative solutions to contemporary environmental and design challenges. This study underscores the exceptional relevance of Leonardo da Vinci's thinking and methodology within the context of contemporary product design, demonstrating that his approaches—although formulated in a Renaissance framework—accurately anticipate both the principles of sustainability and the complex-

ity of the modern design process. Leonardo emerges not only as a precursor to the contemporary designer but also as a visionary who intuitively grasps the necessary integration of science, art, technology, and ecological responsibility.

The analysis of his three methodological dimensions—phenomenological, epistemological, and semiotic—reveals that his approach is neither purely technical nor solely artistic, but rather a genuine form of applied knowledge, in which design becomes a tool for understanding and transforming reality. This integrative perspective provides a solid pedagogical framework for educating future designers, as it fosters critical thinking, aesthetic sensitivity, and sustainable awareness.

In addition to various conceptual architectural applications, the example of the university-level chair design project illustrates the contemporary applicability of Leonardo's methodology. Through the use of diverse tools—from observational sketching to physical prototyping—students are encouraged to participate in an iterative ideation process, where in-depth analysis and understanding of natural phenomena underpin functional and ethically grounded solutions.