Graphic Approaches to Heritage from Descriptive Geometry: A Teaching and Research Experience

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Abstract. The subject Architectural Graphic Expression 1, heiress of its predecessor, Descriptive Geometry, was born in the Architecture degree of the University of Granada with a clear two-pronged approach: teaching, based on the teaching-learning of geometric shapes from architectural references of historical or contemporary heritage, and the research, raised through the realization of a final monographic practice, about one of the surfaces studied in the subject, which must include graphic and formal interpretations of the works selected by students, allowing them to develop their imagination, creativity and spatial vision. In this article, a review of the different learning tools, techniques for the same science –Descriptive Geometry– is carried out, emphasizing, in any case, that the use of examples of heritage architectures facilitates, without a doubt, the understanding of the different geometric shapes, while increasing the motivation of students towards their knowledge.

Keywords: Descriptive geometry · Architectural heritage · 3D models

1 Introduction

As a subject, Descriptive Geometry (DG) has been taught, in the Architecture Bachelor's Degree at the University of Granada, since the birth of the Higher Technical School of Architecture, just over 25 years ago. With the arrival of the degree, in the 2010/11 academic year, it changed its name, from Descriptive Geometry to Architectural Graphic Expression 1 (EGA 1) which, in turn, implied a careful reflection on the specialized approach that it should have, within the graphic teachings, for the training of the future architect. Among the main modifications that were introduced, it is worth highlighting the use of specific examples of architectural, historical or contemporary references, both in the theoretical explanation of each topic and in the approach of most practices, in addition to the realization of an introductory monographic work research.

This methodology has allowed us to establish the essential cross-curricular thematic between DG and other subjects or disciplines of the degree [1], such as, EGA 2, EGA 3, Architectural Graphic Ideation and Introduction to the Architectural Project, History of Architecture, Architectural Composition, Projects and Construction.

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2 Learning Tools in Descriptive Geometry

2.1 Background

The continuous search for methodologies and tools, which contribute effectively to the teaching-learning process of Descriptive Geometry, has become a priority objective for those teachers working in this field in recent years, not only within the Spanish Schools of Architecture, but also beyond our borders [2]. If we add to this both the reduction of credits and hours of DG, with the arrival of the Bologna Plan, and the total abstraction that the traditional teaching of this subject has undergone, when it comes to the students, we obtain a total lack of perception, of the pragmatic or utility of the DG within the profession of the architect.

2.2 Discussion

Researchers such as Álvaro, Galván and Rodríguez developed a Teaching Innovation Project [3] in which they proposed the redirection of the subject, with a more active student participation to approach built architectures, including the computer tools in the classroom. Cisneros and Cabezos [4] also affirm that the constructed architectural references are a teaching resource of great value for the learning of Descriptive Geometry. In another research these authors [5] defend the exclusive use of the computer as a learning tool for geometric models, based on their spatial, three-dimensional vision.

We consider, as Migliari explained [6], that computer software are only tools or techniques, without forgetting that Descriptive Geometry should be understood as a science that requires an essential knowledge of the internal relationships of geometric shapes, their relationships projects and all the operations that we can carry out (depletions, rotations, plane changes). If the computer is the only tool used for the study of Descriptive Geometry, hand management would be lost as a tactile organ that draws on paper, guided by thought [7]. The computer must be another tool, we believe that it is not the only tool, and never completely replace the use of the pencil and the thinking hand on paper.

Therefore, we defend that DG problems should not only be solved in the three-dimensional environment of the computer and that, directly, it obtains the two-dimensional views of the object, because in this way we could be depriving the student of developing his capacity for abstraction from spatial vision to flat representation. The DG should preserve the use of direct procedures as one of its fundamental tools, and not only because it is a subject traditionally designed for it, but because students must learn to think with the pencil, using the different representation systems.

Other researchers have proposed the use of tangible material tools, such as García and Oliva [8] that are committed to the use of transparencies, as layers, that enhance the development of spatial vision and help to understand the results obtained; while Yañez [9] is a strong supporter of the use of three-dimensional teaching material, physical models, in the teaching of Descriptive Geometry, in order to eliminate excess abstraction and instil with clear and precise ideas. In the teaching of DG in the School of Architecture of the Polytechnic University of Alicante, tangible three-dimensional models, not computer models, are also used, obtained through printing of the digital models, which facilitate the learning of some topics of the subject such as Gnomonic. One of them is an ingenious instrument that allows us to know the position of the Sun, in its seven main solar paths, which correspond to twelve very significant days of the year [10]. The model is also valid for any point on the earth's surface, that is, it can be used in different latitudes.

3 Methodology and Resources of Work Line

The subject EGA 1, taught in the Architecture Degree at the University of Granada, is structured in four large blocks: Dihedral System, Bounded System, Perspectives – axonometric and conical– and Intersection of Surfaces, Shadows and Gnomonic. The methodology each topic is approached with is the result of the teaching research carried out in recent years, aimed at breaking the isolation that, in the old Descriptive Geometry, meant the graphic study of geometric shapes –spheres, polyhedra, prisms, pyramids, cylinders, cones, warped surfaces and intersections– in the different representation systems, depriving them of a direct relationship with the architectural ideation.

From the first topic of the subject, the sphere, students learn the graphic representations of the different geometric surfaces through theoretical-graphic explanations, applied to architectural references. In this way, a double objective is achieved: the knowledge of relevant architectures, conceived from the geometric forms explained in EGA 1, and the resolution of practical exercises, using architectures or architectural objects already constructed or capable of being able to materialize.

As a significant example, on the topic of the sphere, an exercise was proposed inspired by the cover of the Kresge Auditorium of the Massachusetts Institute of Technology (USA), designed by the architect Eero Saarinen, built between 1953 and 1955. In the practice carried out by the students, belonging to the Dihedral System, they were asked to determine the plan, elevation and profile of the resulting spherical vault when sectioning the given hemisphere of centre O, by the planes defined by the pairs of points A, B and C, belonging to the spherical surface, and the centre of the sphere. As in the Saarinen project, the solution dome was supported by three points [11], vertices of a triangle, although unlike this, the one proposed for practice was not an equilateral triangle but isosceles, so the students had to make at least two vertical plane changes (Figs. 1 and 2).

Fig. 1. Kresge Auditorium, Massachusetts Institute of Technology. Cambridge (Massachusetts), United States, 1953–1955. http://intranet.pogmacva.com/en/obras/65050.

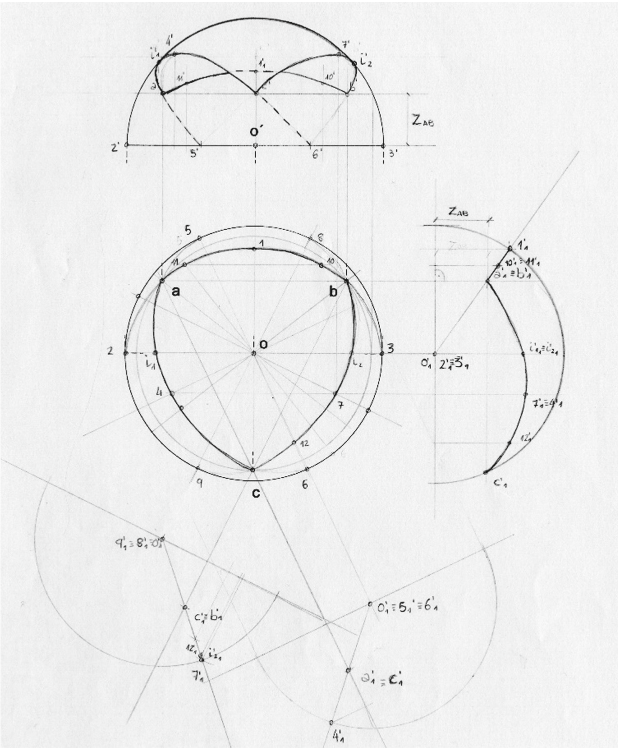

Fig. 2. Practical exercise of a hemisphere, sectioned by three planes. Student: José Garófano.

For the study of the Bounded System, three-dimensional physical models are used in the classroom, with the aim of facilitating the spatial understanding of the architectural reference and the translation from the tangible volume to the two-dimensional graphic representation, on the drawing plane. This system of representation is the most appropriate, in architecture, for the graphic representation of inclined roof plans and, in topography, for the representation of land and for the calculation of earthworks in the execution of platforms and roads [12].

The practical exercises of axonometric and conical perspectives are made from an architectural reference of the historical heritage that, taking into account the students of Architecture will know in all its dimensions (author of the work, history, typology, use, construction system, materiality). In the 2017/18 academic year, students in subgroups A2 and B2 of EGA 1 made, among others, an isometric perspective of the Maison de Surveillant de la Source de la Loue, designed by the architect Claude-Nicolas Ledoux, between 1775–1779, for the ideal city of the Salinas de Chaux (Figs. 3 and 4). References of movable objects as relevant as the 1923 Schroeder table of the architect Gerrit Rietveld (Figs. 5 and 6) were also used for the practical exercises.

In the last block, the students receive knowledge of Sciography –awareness of shadows– and Gnomonic –awareness of the Sun's trajectories on the horizon– that will allow the tracing of solar cards and the calculation of shadows in real situations, according to latitude, orientation, solar time and day of the year, using a pencil and paper. In the same way that we distinguish between types of conical and cylindrical projection, we can talk about types of conical and cylindrical shadow, as we refer, respectively, to the one produced by a spotlight with a vertex at its own point –artificial light–, or the one generated by a sufficiently distant light bulb, comparable to a degenerated cone in a cylinder, with an improper vertex and parallel rays –usually sunlight. The cylindrical shadows are worked in the classroom in Dihedral System, as a method of plotting perspectives, since through the calculation and drawing of the shadow of an object or architectural reference, we obtain an oblique cylindrical projection of said object on a flat surface, by the incidence of light rays parallel to a given direction. Therefore, it is important for students to be aware that the shadow is a projection –a perspective– of the object, which corresponds to the view that an observer would have of it from the distant light source. The calculation of shadows is also performed in the Axonometric System and, although models exposed to sunlight by the students themselves are used, so that they understand the generation of shadows in real space and are participants in their own learning, both own shadows and thrown on planes, mainly horizontal and vertical, students must use direct procedures to obtain shadows on the paper or drawing plane.

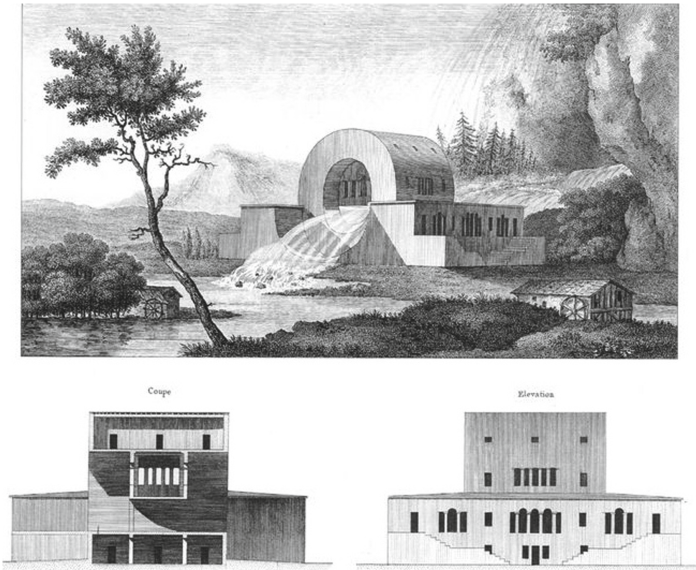

Fig. 3. Project for the Ideal City of Salinas de Chaux. Maison de Surveillants de la Source de la Loue. Claude Nicolas Ledoux, 1775–1779.

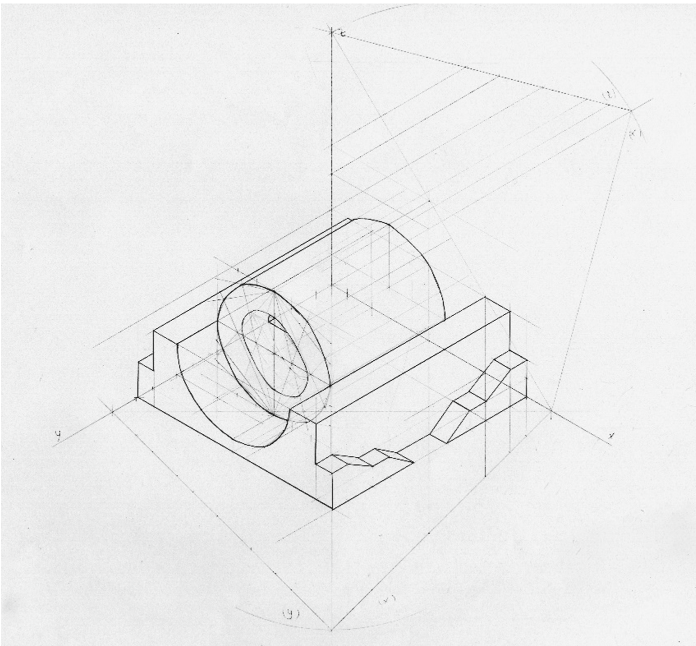

Fig. 4. Practical exercise of axonometric perspective. Student: Alba Ordóñez.

Fig. 5. Schoeder table. Gerrit Rietveld, 1923.

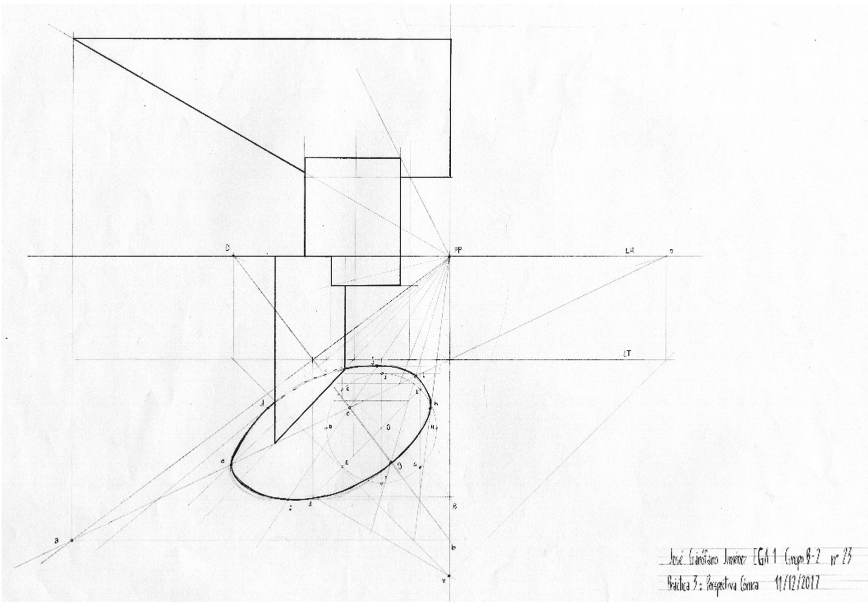

Fig. 6. Practical exercise of conical perspective. Student: José Garófano.

With respect to the field of shadow calculation and its learning, it is necessary to highlight the experience carried out in the School of Architecture of Valladolid [13], in which students had to obtain figurative shadows of representative architectures, by using of computer software and the subsequent printing of 3D models. The procedure did not consist in subjecting such architectures to a spotlight, but in using different geometric objects that managed to produce the figurative shadow, which allows the architectural reference to be easily identified. Although it is, without a doubt, a pioneering and relevant experience in this area, we think it would be very interesting if it could be completed with the use of direct procedures, both for the tracing of shadows, without dispensing with the Dihedral System, as in the making of mock-ups with traditional materials. In this way, students would think, using their hands as a vehicle, the simple pieces with which they could also obtain figurative shadows.

At the School of Architecture of the University of Granada, the curriculum is designed in such a way that, once the basic principles of solar paths and calculation of shadows have been learned through direct procedures, both in EGA 1 and EGA 2, the student is prepared to introduce the necessary data to a software, such as 3DStudio or Lumion, and that the program automatically calculates the shadows, teaching that he/she will receive in the next course, in Architectural Graphic Expression 3.

4 Monographic Work: Initiation to Graphic-Formal Inquiry

In addition to the learning practices proposed within each topic, students must carry out a final monographic work, whose main objective is to initiate the students of Architecture in the inquiry of geometric shapes, which are used as germ or main idea of the architectural project. The analysis of three is requested, if the individual option is chosen, or an analysis of five, if one works in pairs, architectural projects or constructed works, based on the geometric forms of the theme assigned to each student.

Students face one of their first challenges when it comes to research and formal and graphic reinterpretation of geometric models used in architectural projects and works. While it is true that the computer provides three-dimensional modelling tools for complex surfaces, whose difficulty of representation using traditional procedures could leave them out of the syllabus, these can also be solved with three-dimensional physical models, as some groups did, using pop-up as a formal resource in their research work. An example of helical surfaces could be the Tower designed by Vladimir Tatlin in 1919, Monument to the Third International, 400 m high and double helical structure (Figs. 7 and 8).

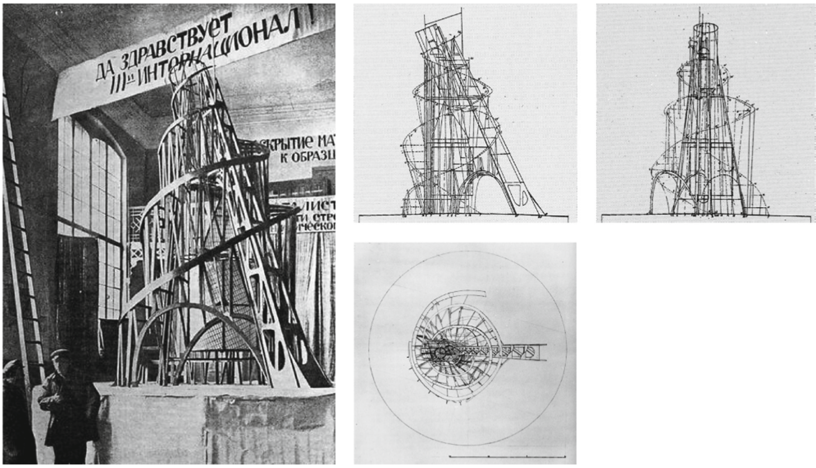

Fig. 7. Monument to the Third International. http://intranet.pogmacva.com/en/obras/65320.

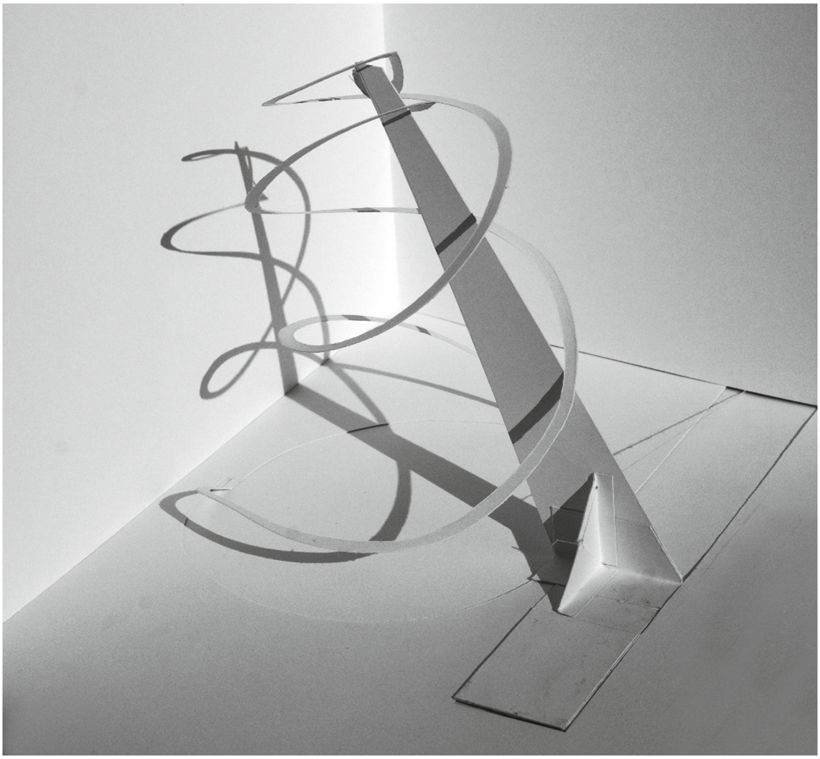

Fig. 8. Pop-up of the Monument to the Third International. Students: Alejandro Martín and Liliana Muñoz.

Other groups also materialized the surfaces under study in mock-ups, made of wood and cardboard, such as the hyperbolic paraboloid, ruled surface warped generated by a straight line that moves parallel to a master plane and supported by two straight lines that cross. We can obtain generatrixes in two directions, as shown in the model of Fig. 9.

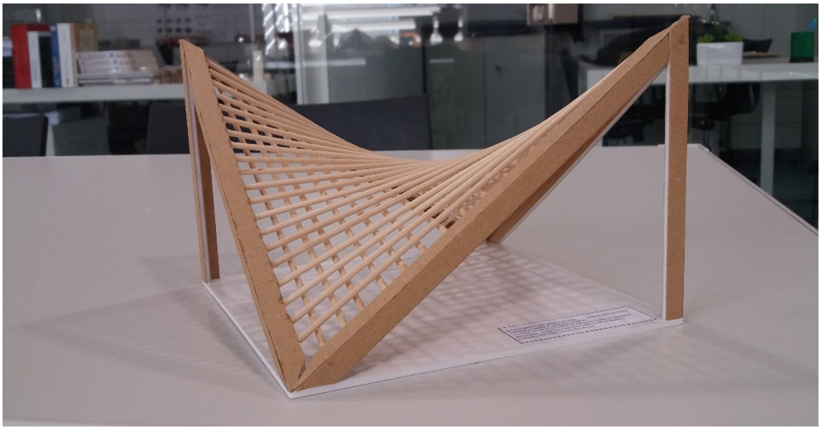

Fig. 9. Hyperbolic paraboloid model. Students: Ángel Martínez and Patricia Moya.

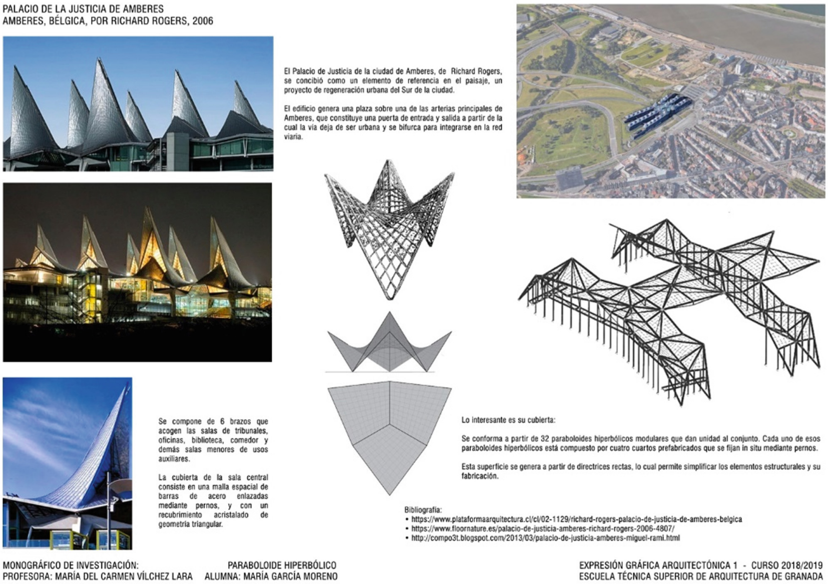

Fig. 10. Panel of the monographic work of the student María García. Hyperbolic paraboloid. Palace of Justice in Antwerp. Richard Rogers, 2006.

The manual practice that requires the realization of mock-ups involves a physical and tactile experience for the students, in whose hands are a large part of the cognitive processes. For this reason, traditional graphic techniques –drawings and mock-ups– that require manual gestures, guided by the eye and mind, must continue to be present in the training programs of architecture students [14].

In the final practice of the subject, students also face one of their first format composition challenges and must demonstrate their ability to explain, through a successful organization on the sheet, the chosen architectural work, as well as the forms original geometric patterns, through texts, images and graphic representations, with special attention to the hierarchy and order of the written and graphic language used (Fig. 10).

5 Conclusion

The teaching-learning process of geometric shapes and the different representation systems, linking it to projected or constructed architectural references, has led to quite satisfactory results among EGA 1 students. This, without a doubt, is due to the orientation of the subject towards the knowledge and graphic representation of very significant architectures, which directly affects the perception, by the students, of the usefulness and interaction of this discipline with others within the same field of knowledge or belonging to another area, essential for the integral graphic formation of the future architect.

The inquiries of the graphic and written sources of the geometric surfaces, present in the architectural heritage, made by the students of the subject, have allowed them not only to start research in Architecture, but to develop their imagination and creativity with formal reinterpretations and materials of this Heritage.

Models have been a resource for formal manipulation since ancient times – thinking with your hands– and a mean of architectural representation. Its use implies the rebirth of the physical three-dimensional model in modern times, as a complement to the ubiquitous digital modelling –not tangible–.

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