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ADDRESSING SUSTAINABILITY. CONSTRUCTION OF A PROTOTYPE AS A TEACHING DESIGN TOOL

ABORDANDO LA SUSTENTABILIDAD. LA CONSTRUCCIÓN DEL PROTOTIPO COMO HERRAMIENTA PROYECTUAL DOCENTE

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RESUMEN

Utilizar la construcción física de un prototipo como herramienta educativa no es una propuesta nueva, aunque puede ser innovadora en el contexto actual de renovación conceptual vinculado al desarrollo sustentable. En la Escuela de Arquitectura de Sevilla existe una gran tradición investigadora en materia de sustentabilidad, pero poco extrapolada a la enseñanza. También es necesaria una mejora significativa de la educación desde el ámbito metodológico. En este sentido, los concursos proporcionan una oportunidad que define una situación potencialmente afortunada para la innovación educativa. Partiendo de esta base, la presente investigación tiene como objetivo comprobar cómo la construcción de un prototipo a escala real, como estrategia metodológica educativa activa, de la mano de una metodología de diseño bioclimático consolidada en dicha escuela de arquitectura, permite lograr grandes resultados tanto en términos educativos como bioclimáticos. La metodología educativa empleada aúna las siguientes directrices: el taller como ámbito integrador para el aprendizaje arquitectónico; la construcción de un prototipo como situación educativa que trasciende lo arquitectónico; la conceptualización de los nuevos retos marcados por la sustentabilidad y su aplicación práctica y efectiva al proyecto, diseño y construcción arquitectónicos. Todas herramientas puestas en valor dan respuesta efectiva a las carencias actualmente detectadas e interiorizadas del aprendizaje-enseñanza y, por tanto, del quehacer arquitectónico.

Palabras clave
prototipos, aprendizaje activo, diseño arquitectónico, concurso.

ABSTRACT

Using the physical construction of a prototype as an educational tool is not new, although it can be innovative in the current context of conceptual renewal linked to sustainable development. At the School of Architecture of Seville, there is a great research tradition on sustainability, but little is extrapolated into teaching. There is also a need for a significant improvement in education from the methodological point of view. In this sense, competitions provide an opportunity that defines a potentially rewarding situation for educational innovation. From this starting point, this research aims at verifying how the construction of a full-scale prototype, as an active educational methodological strategy and following a bioclimatic design methodology consolidated in said School of Architecture, allows achieving great results both in educational and bioclimatic terms. The educational methodology brings together the following guidelines: the workshop as an integrating environment for architectural learning; the construction of a prototype as an educational situation that transcends the architectural; the conceptualization of new challenges marked by sustainability and their practical and effective application to the architectural project, design, and architectural construction. All the tools are valuable and effectively respond to shortcomings detected and internalized in teaching-learning, and, consequently, architectural activities.

Keywords
prototypes, active learning, architectural design, competition

INTRODUCTION

ARCHITECTURAL DESIGN AND SUSTAINABILITY

Modern architecture education has been accompanied by multiple project design tools. Most of them are not new, although they are reinterpretations or reinventions of past experiments, which try to give value, once more, to approaches that allow responding to the current challenges and needs of architectural teaching. The start of this century has made the crisis of the architectural approach and profession evident. As professionals, we are not suitably responding to new challenges, we do not provide society with the service it needs, and architectural education and teaching must respond to this reality with vigor, change, reinvention, rigor, and, above all, a lot of enthusiasm.

The requirements that currently need to be addressed and faced are two-fold: conceptual and methodological. Indeed, on one hand, a conceptual revision of the architectural approach is essential (M. López de Asiaín, 2010), which involves reflecting on the current needs of society linked to sustainable development (ONU, 2015). On the other hand, it is also key to review and reintroduce teaching methodologies adapted to new educational profiles and the conceptualization of new approaches (Granero & García Alvarado, 2014).

Many tools have been designed and experimented with over the past century. However, an updated reinterpretation and adaptation are necessary, and therein lies the innovation of the process. The actual architectural design and construction process (Fernández Saiz, 2016) can be understood as one of research in itself, whose results and evaluations allow progression by testing, and understanding architecture as an experimental science despite the multiple potentially feasible methodological approaches (M. López de Asiaín, Echave & Fentanes, 2005). There have been numerous teaching innovation experiences carried out over the last decade at the School of Architecture of Seville (ETSAS) (Ramos Carranza, 2018). All of them involve a gradual and continuous effort to improve the teaching methodologies and tools teaching is approached with, aware of the need to review the educational strategy that motivates and generates knowledge transfer.

Sustainability in architecture, bioclimatic adaptation, or energy efficiency, are inescapable topics and concepts in this approach. However, the approach from different subjects and architectural knowledge, neatly cataloged and sometimes poorly related to the academic sphere, although fully interconnected, is methodologically diverse and enriching, so its integration into architectural projects is fundamental (Alba Dorado, 2019). In this sense, certain research strategies have encouraged collaboration and debate between areas of knowledge, subjects, and approaches, generating a climate that calls for change and improvement which numerous professors have leveraged, making interesting contributions (Herrera-Limones, 2013; Martínez Osorio, 2013). As an relevant example, during the experimental phase of the European project, *Educate* (Altomonte, 2009), workshops were held where several ETSAS professors participated (Blandón González, 2018; Blandón Gónzalez & Vallés Sisamón, 2019; Galán Marín, 2018; García Sáez, 2018; Pedreño Rojas, 2018; Rivera Gómez, 2018; Roa Fernández, 2018). There, the teaching projects of different subjects were worked on to incorporate specific environmental competencies, to ensure that students acquired the necessary skills to work from a sustainable development-based approach. In the same way, and from the same European research project, an experience linked to a European architecture competition for students was carried out.

Figure 1. Cover of the Educate Prize Publication.
Source: European Educate Project (EDUCATE Project Partners, 2012a)

The *Educate* Prize (M. López de Asiaín & Escobar, 2013) (Figures 1 and 2) proposed, as a challenge, a more sustainable habitat architectural intervention and proposal, designed in a location defined and chosen beforehand by the students. They had to be tutored by professors who had included environmental competencies in their teaching project and would use the *Educate* portal as a potential teaching tool (Cangelli et al., 2012). This portal included specific information and content

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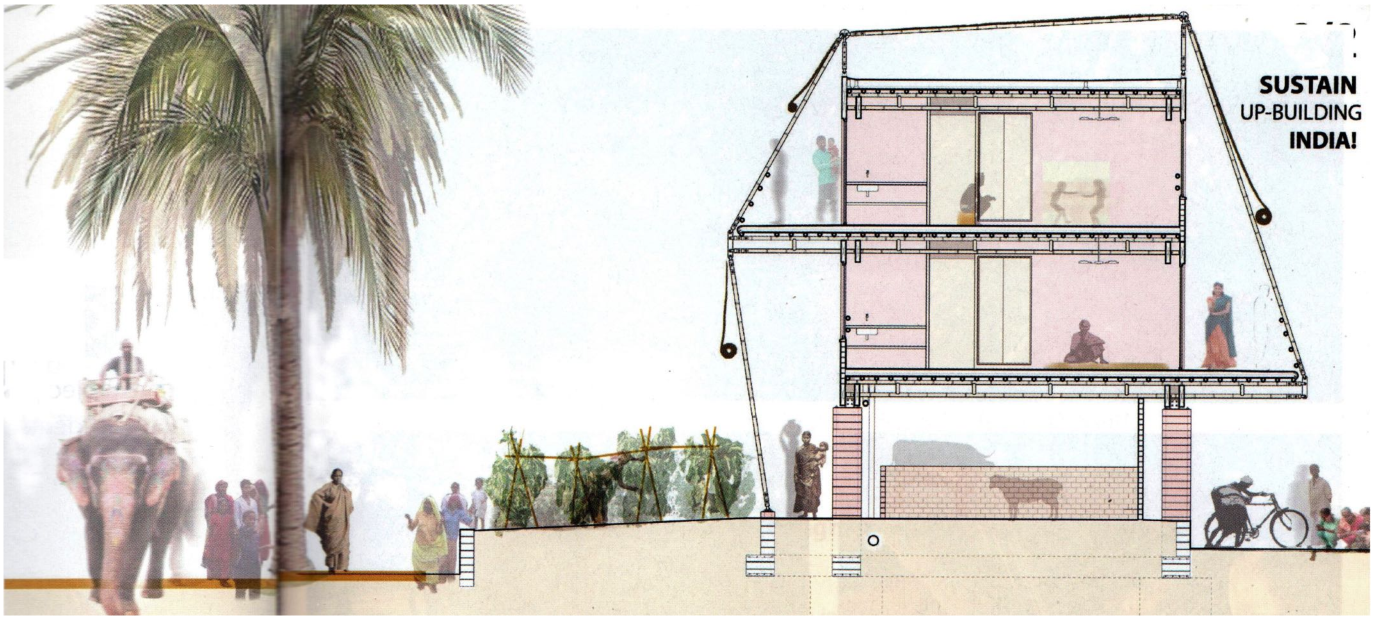

Figure 2. Project submitted to the Educate Prize. Source: European Educate Project (EDUCATE Project Partners, 2012a).

on the subject, from conceptual explanations and calculation guidelines, to design examples and even practical professionally developed and built examples. It also included communication tools, information, and debate among students, professors from all participating Schools of Architecture, researchers (Altomonte *et al.*, 2012) (more than 30), specialists in the field, and participants in the research project.

This experience proved conclusive in several respects. First, it showed that the interest of educators in incorporating environmental and sustainability matters in architecture teaching was real and, at the same time, an urgent need (*EDUCATE* Project Partners, 2012b). It was also confirmed that the rigorous doctrinal corpus on the subject was fully defined, completed, and accessible to both educators and students. And, finally, it showed that there was a great need to develop new teaching strategies and methodologies or reinterpretations, appropriate to the new transversal approaches and concepts that should be incorporated into teaching (Masseck, 2017).

It is worth mentioning that the School of Architecture of Seville has professors whose personal research backgrounds have been dedicated to the environment and sustainability in architecture and urbanism for decades. The oldest and most relevant case is that of Jaime López de Asiaín, who has incorporated environmental and bioclimatic analysis of buildings and urban spaces since the 80s (González Sandino & J. López de Asiaín, 1994) in architectural composition classes, within the framework of the Bioclimatic Architecture Seminar (Herrera-Limones, 2013). The analysis methodology he employs, subsequently defined and expanded (M. López de Asiaín, 2010) (Figures 3 and 4), is the foundation of professional and research architectural experimentation and, above all, the methodological and conceptual basis on which experimental case studies made during several investigations (González Sandino & J. López de Asiaín, 1994; J. López de Asiaín, 1997; J. López de Asiaín, 2001), as well as the present experience, are based. It is noteworthy to say that the approach this author develops combines architectural praxis with teaching and research, which allows the integration of the three dynamics and their feedback. It is difficult to determine the dynamic that incorporates, ahead of time, the bioclimatic and sustainability approach: the methodology of analysis of the types of architectural composition; the research on the hygrothermal behavior of a prototype for an Andalusian dry warm climate; the experimentation on a built case or the measurements made; and the extrapolation to other architectural projects of a larger nature. Therefore, these are analyzed as a whole to define the methodological strategy that feeds into this research.

Research and physical project experimentation are not only simulated but nurture and perfect teaching by reformulating analysis and decision-making methodologies. In turn, this teaching improves the professional practice, not only the personal but also the plural practice of the architect, by promoting the development of teamwork skills, fundamental nowadays, for all students, whether undergraduate, master's and/or doctoral, who subsequently put their bioclimatic capacity into practice in numerous projects (Figure 5).

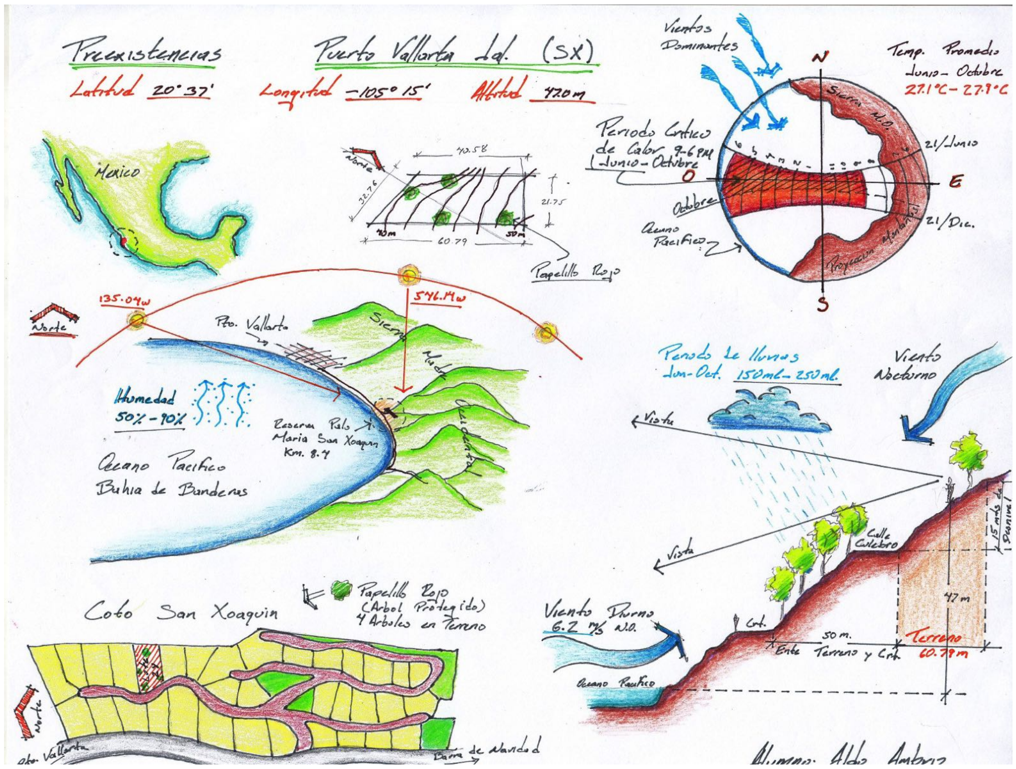

Figure 3. Methodological exercise of bioclimatic analysis. Corrections of the environment. Source: Student Aldo Ambriz.

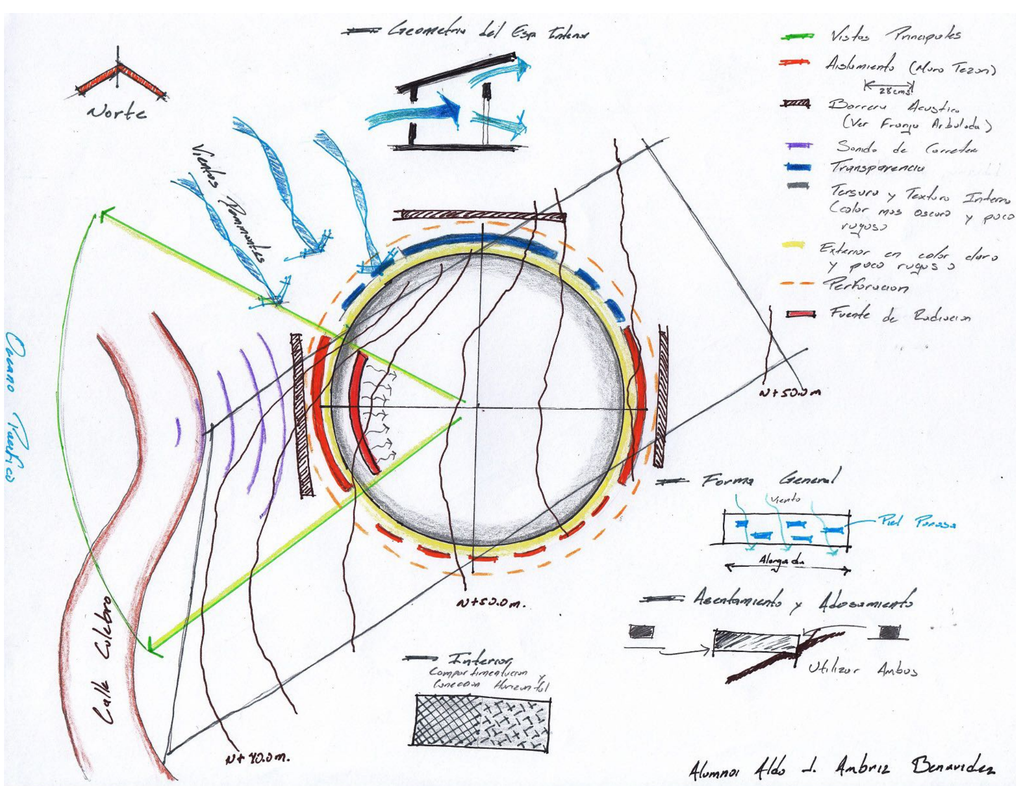

Figure 4. Methodological exercise of bioclimatic analysis. Bioclimatic analysis of the building. Source: Student Aldo Ambriz.

Figure 5. Bioclimatic housing project in Mallorca.Source: Student Luis Velasco Roldán

RESEARCH- NETWORKING- PREVIOUS EXPERIENCES

The progress of research, in terms of sustainability in architectural project design, has been influenced and helped by international research networks. Renowned Seminars in the field in recent decades, such as those of PLEA (Passive and Low Energy Architecture[2]), have generated an international research support network without which the exchange of experiences, progress, and innovations made would not have been possible. For years, this network has provided contact between researchers from the School of Architecture of Seville and other European and Latin American universities that has allowed discussing, experimenting, and improving the gradual incorporation of research achievements into architectural teaching, both in terms of content and teaching methodology.

One of the experimental references used for the methodology employed in this research was the one performed at the School of Architecture and Design of the University of Colima 2012-2013 for complementary subjects of project design, habitat, and urban project (M. López de Asiaín &y Luna Montes, 2014). During these courses, several innovative approaches are used: the teaching program itself and its temporary intensification as an intensive workshop; the teaching methodology followed; and the bioclimatic and sustainability analysis methodology (Figure 6), transmitted to the students. Progress in this experience has later been incorporated and extrapolated to teaching at ETSAS in several subjects and, currently and to a large extent, constitute the basis of the teaching innovation processes of the authors.

Based on these experiences, a bioclimatic analysis and project design methodology are developed (Figure 7). The purpose of this study is to verify this bioclimatic analysis and project design methodology in terms of the educational experience, through the construction of a full-scale prototype in the context of the Solar Decathlon Europe 2019 Competition.

2 "PLEA is an organisation engaged in a worldwide discourse on sustainable architecture and urban design. It has a membership of several thousand professionals, academics, and students from over 40 countries. PLEA stands for "Passive and Low Energy Architecture", a commitment to the development, documentation, and diffusion of the principles of bioclimatic design and the application of natural and innovative techniques for sustainable architecture and urban design. PLEA serves as an open, international, interdisciplinary forum to promote high-quality research, practice, and education in environmentally sustainable design. PLEA is an autonomous, non-profit association of individuals sharing the art, science, planning, and design of the built environment". (Passive and Low Energy Architecture, 1982)

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Figure 6. Concept of sustainability and habitability. Student work from the School of Architecture of Colima, Mexico. Source: Student Carlos Baltazar Ortiz.

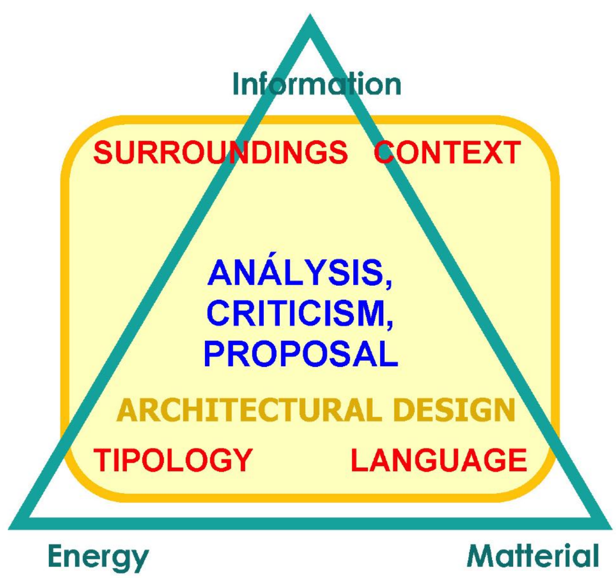

Figure 7. Outline of the project methodological process. Source: Preparation by the authors.

This bioclimatic design methodology, a synthesis of the broad, complex, and collaborative research process developed at ETSAS, following what has been expressed in the previous paragraphs, uses several consolidated tools. Some of them are solar geometry analysis (Serra Florensa & Coch Roura, 1995), and the psychrometric graphs of Victor Olgyay (Olgyay, 1992), Baruch Givoni (Givoni, 1992), and Szokolay (Szokolay, 2008). It is also supported by several computer programs, such as Heliodón, Archisun, Design-Builder, or the unified Lider Calener Tool, used greatly in Spain.

To attain the objectives set out, this experience defines a necessary educational methodological process, based on active learning by projects, which is detailed below.

METHODOLOGY

The methodology used in this research focuses on the development of the following phases:

- Definition of an educational framework based on previous consolidated local experiences

and relevant international experiences, to incorporate sustainability in architecture teaching.
- Determination of the most suitable educational methodology and definition of specific variables that condition it and/or the educational methodological approach.
- Determination of the case study.
- Development of the educational experiment.
- Extraction of conclusions and learnings.

The educational methodological approach has three dimensions: the knowledge framework, based on the concept of sustainable development in all its breadth (environmental, social, and economic); the work methodology, focused on project-based learning (the student learns to learn); and the physical construction of the proposed prototype, as a materialization of the solved project and as an added problem to be solved by the students.

THE SOLAR DECATHLON COMPETITION AS A POTENTIAL FRAMEWORK

The Solar Decathlon 2019 Contest (Cobo-Fray & Montoya-Flórez, 2021) constitutes an optimal experimental framework for educational research (Chiuini, Grondzik, King, McGinley & Owens, 2013). It is run for several reasons:

- It incorporates, as a specific project proposal requirement, the environmental, social, and economic sustainability approach.
- In contrast to previous editions, urban aspects acquire greater importance and, thus, the urban approach incorporates the need to work from urban regeneration and social resilience.
- The competition's approach incorporates a multitude of transversal aspects complementary to the specific architectural one (M. López de Asiaín & Cuchi-Burgos, 2005), that force giving a broad response, beyond the architectural area itself[3].
- It is a competition by and for students, who are firstly responsible for their learning. Professors are incorporated as tutors and mediators on a secondary level, promoting more dynamic, practical, innovative, and educational teaching methodologies, from an approach based on the concept of sustainability.
- The competition's specific requirement, to build an experimental prototype, provides a suitable work framework and teaching research to check the objectives of the research presented.

Since its inception, the Solar Decathlon Competition has set out the bioclimatic and energy efficiency component as a core requirement of its proposals and the prototypes submitted for the competition had to comply with this. The fact that the prototype formulated as the competition's objective was always a single-family home, along with the North American urban planning tradition that prioritizes single-family housing over collective housing, has made it difficult to incorporate urban approaches that are more consistent with the paradigm of sustainable development.

RESULTS AND DISCUSSION

For the Higher Technical School of Architecture of Seville, the sustainability-based approach the contest has is a priority and is absolutely necessary in educational terms. This is why the participation of the University of Seville team is included, interpreting it in terms of educational research. It is only recently that the competition has begun to emphasize the relevance of urban aspects in terms of sustainability (Herrera-Limones et al., 2017), where educational research acquires meaning from a housing prototype-built urban habitat proposal (Figure 8).

On the other hand, the participation of the University of Seville's Solar Decathlon Team transcends the architectural sphere. The opportunity to work with students and professors from different Schools and areas provides a framework for transdisciplinary educational research (Moreno Toledano, 2017), compelling and relevant today. The team made an open invitation to the different Schools of the University of Seville to take part through their deans and, ultimately, the professors and/or researchers of the Schools of Mathematics, Physics, Medicine, Education Sciences, Communication, Psychology, Economics and Business, Fine Arts, Biology, the Office of Development Cooperation, the School of Computer Engineering, the Polytechnic or the Higher Building Engineering, took part in the 2019 project (Europe and Latin America-Caribbean) (Herrera-Limones et al., 2020). The experience is also enriched by the support of researchers from other universities, who are invited as experts during the contest.

3 The 10 items defined as goals for the Solar Decathlon are: architecture; engineering and construction; energy efficiency; communication and social awareness; urban integration and impact; innovation and viability; comfort conditions; housing operation; and energy balance (see: http://sde2019.hu/index_en.html).

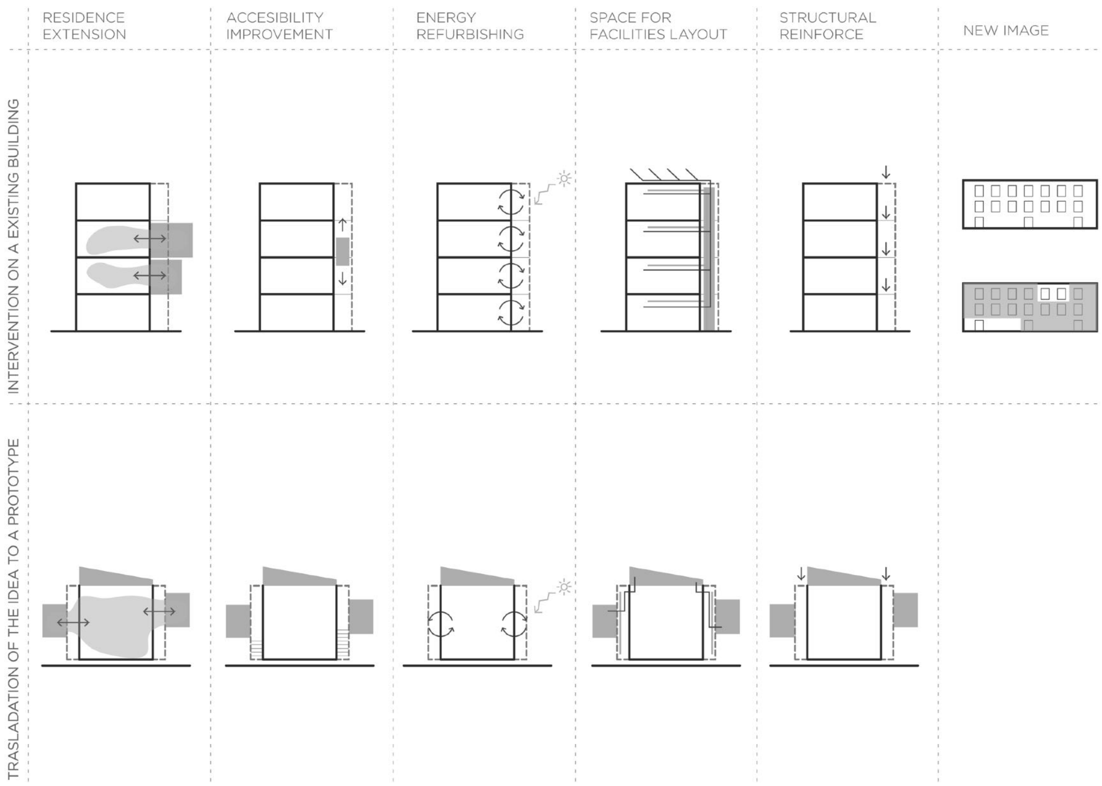

Figure 8. Outline of the "type" developed. Integration and urban conceptualization transferred to the architectural object. Source: Preparation by the authors.

Several teaching-innovation networks, currently active at the School of Architecture of Seville, also support the research project. Their methodological contributions are key. Other parallel investigations provide support to the proposed experimentation. This is the case of the University of Seville's Arus team, which works on the design and construction of racing car and motorcycle prototypes. The collaboration and exchange with this team allow, among other things, to progress and debate on more generic, but highly relevant matters considering the educational-methodological approach being applied, like logistics, management, the knowledge transfer between students of different courses, and student leadership, etc.

Along with the consolidation of the bioclimatic design methodology, a second objective within the framework of this research lies in defining and experimenting with the potential of the built prototype (Fernández Saiz, 2016), as a tool that incorporates the real professional world into teaching. In this way, the logistical, management, economic, and organizational aspects are part of the learning itself, apart from the purely disciplinary aspects linked to a more sustainable architectural design. Thus, numerous previous experiences in different contexts, accompanied by those mentioned at the Seville School of Architecture, have provided the base for the educational methodological approach applied here.

The definition of the 'type' or 'prototype' is an architectural educational exercise, whether academic, professional, or traditional, which allows searching and delving deeper into the project conception of the architectural object, verifying specific requirements (Figures 9 and 10). In this case, those established by the concept of sustainable development are chosen. In the same way, the suitability of the prototype model to its context, defined as a base requirement of the bioclimatic approach, is analyzed.

From the conceptualization, the methodology employed for architectural design based on a bioclimatic analysis of preexisting cases (Figure 9), ensures an environmental field in project design (Figure 10), while the social and economic requirements, studied from understanding and dialog, both with the market and with citizens and their specific needs, condition its final materialization decisions and construction definitions. The most relevant aspects considered, and the achievements attained, are detailed in Table 1. The project is laid out as a complex global problem to be solved and is approached from different perspectives and architectural requirements, problem by problem, decision by decision, understanding the process as a round trip that provides feedback as it moves forward, reflects, and faces crises step by step.

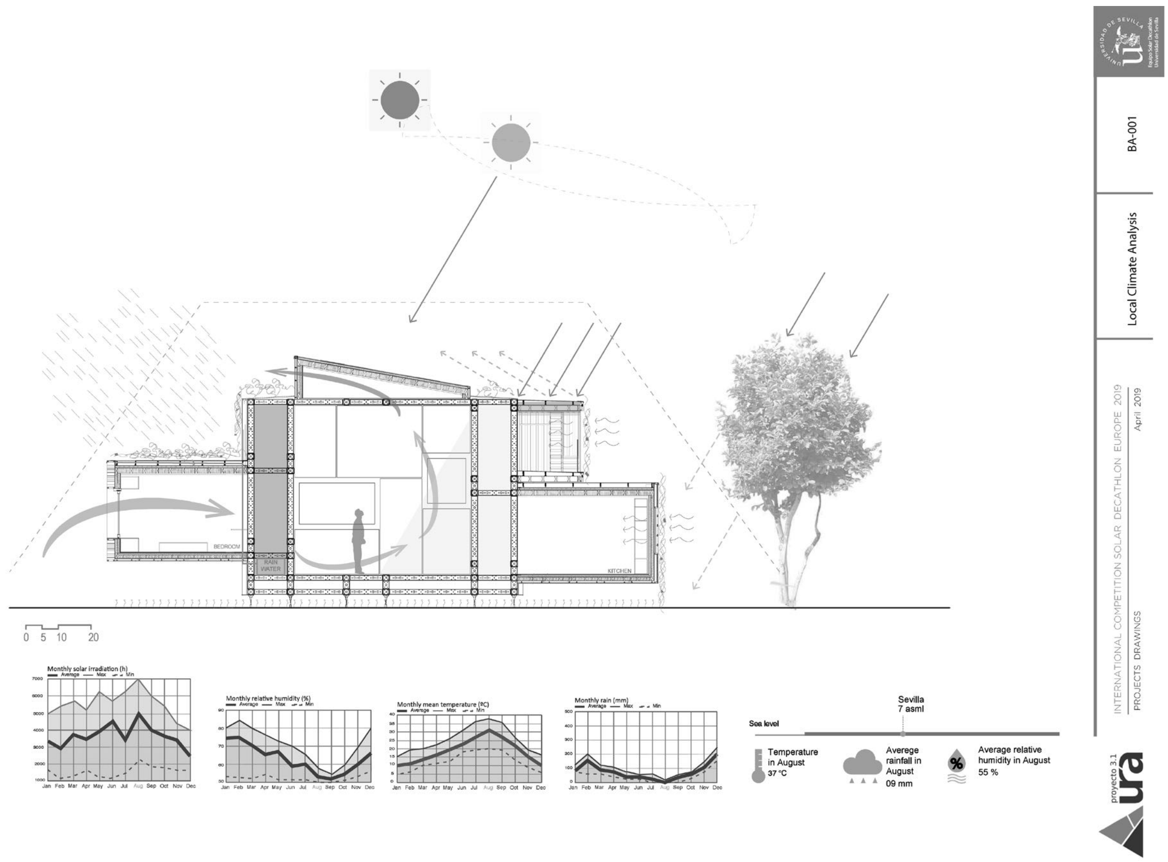

Figure 9. Outline of the bioclimatic analysis of pre-existences and prototype behavior. Source: Preparation by the authors.

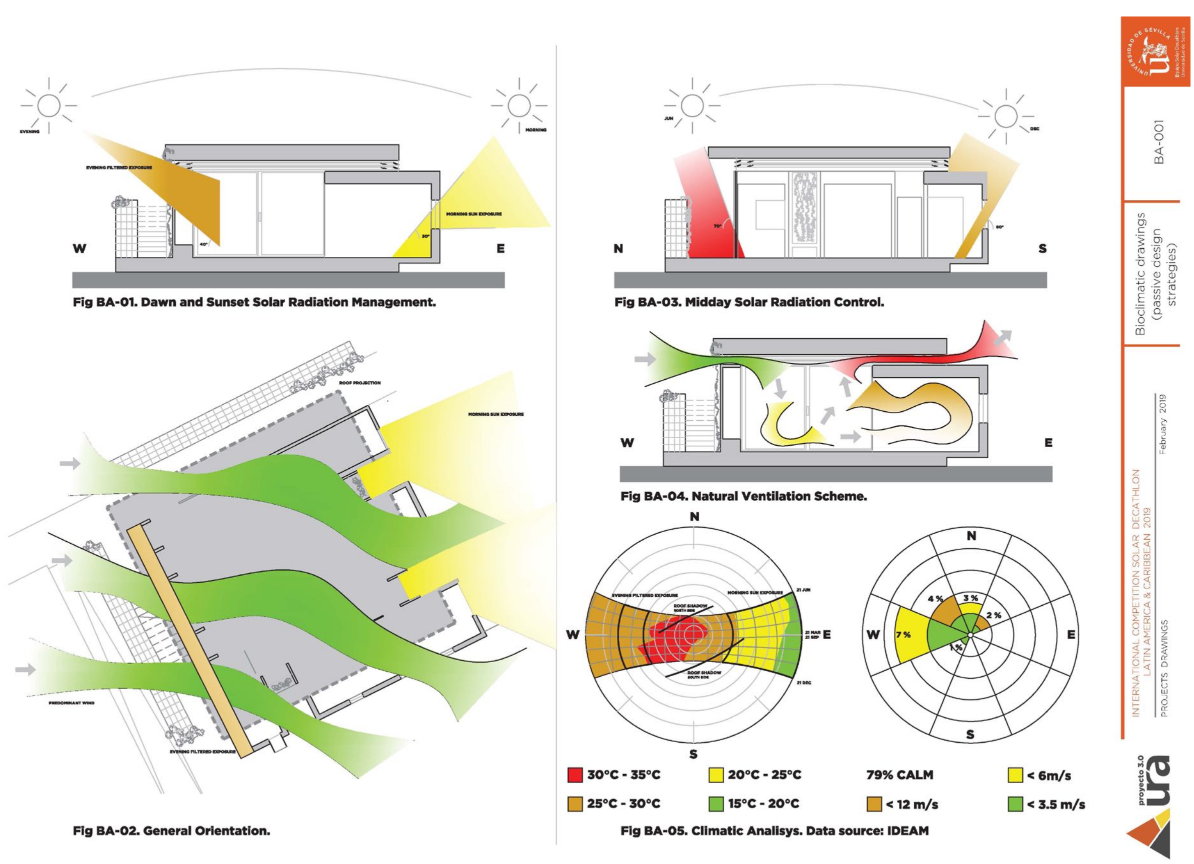

Figure 10. Bioclimatic behavior of the prototype. Source: Preparation by the authors.

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Economic sphere	
A "Low-Cost" prototype is made, that prioritizes the balance between resources consumed and results obtained.	
Social sphere	
The prototype is developed in the field of urban planning and management, based on the regeneration of an already built urban fabric, with certain characteristics of functional obsolescence and a high degree of energy poverty. Proposals for new building floorplans, that address the consumption and occupation of new unbuilt land, are avoided.	
The objective is to reduce, reuse, and recycle not only the waste generated but also the existing urban fabric.	
Environmental sphere (bioclimatic and ecological)	
Optimization of material resources	Within the framework of the "Low-Cost" concept, the use of recycled, rented, or borrowed products and systems is prioritized, to reduce the consumption of resources, emissions, and the energy consumed in the entire cycle. Studying light prefabrication systems allows controlling and reducing the amount of material involved and the emissions derived from the building process.
Reduction of energy consumption through passive strategies and the promotion of renewable energies	The use of passive and capture systems is prioritized to use natural energies and the dominant air currents of the environment. Cross ventilation, a central patio, atomization of the spaces to facilitate their control, daylighting, double skin, solar control, and correct orientation are used. High-efficiency thermal insulation is used throughout the envelope to avoid thermal bridges, with controlled ventilation to improve indoor air quality and guarantee internal comfort. Simulations are carried out to specifically optimize the choice and use of high-performance active lighting and conditioning systems and equipment.
Reduction of waste and emissions	In the construction, priority is given to the use of recycled or rented materials and systems in the structure, in the enclosures, furniture, facilities, and products that have a second useful life and can be remanufactured in other construction processes. The use of prefabricated systems facilitates the subsequent reuse and assembly in other projects. The use of internal recycling systems for rainwater, gray water, and waste generated in the construction itself is also studied.
Decrease in the maintenance, operation, and use of buildings	An exhaustive study of the parts of the prototype is made considering their life cycle, maximizing the so-called "three Rs" (reduce-reuse-recycle). Some parts used for the prototype construction are rented or borrowed, and others, after the competition, are sold for their reuse. The prototype is designed based on a surface and durability consistent with the contest's exhibition. However, in the continuous monitoring of its service life cycle, once the exhibition is over a large part of the prototype is sold to a Hungarian citizen. This makes it possible to extend the service life of these modules and save transport resources.
Improvement of the quality of life of the building's occupants	The study of the prototype's internal comfort is one of the pillars of previous studies based on natural ventilation, a flexible functionality, perfectible, and adapted to the needs of new family models. A balance is achieved between the use of domestic automation systems that integrate all these functions and optimize overall energy consumption, with the incorporation of passive devices to regulate comfort (temperature, air movement, and adequate indoor humidity), in addition to a specific use of active support systems.

Table 1. Sustainability aspects addressed in the study and construction of the prototype. Source: Preparation by the authors.

In the construction area, the tradition maintained by Bauhaus regarding the trade as an essential and primary part of the architect's training is recovered (Ramos Carranza, 2010), the workshop being the space required to initially prepare the project and, subsequently, for its constructive development. The physical construction of the prototype (Fernández Saiz, 2016) is an educational opportunity of special relevance (Figure 11) since it forces students to face numerous challenges that, otherwise, would not be easy to raise. Firstly, time management related to onsite management of different agents; second, the necessary decision-making, both constructive and structural, since the prototype 'has to be built'; third, the production of information needed to build the prototype regarding planimetry, and; fourth, the management and use of team dynamics.

The time management of the work is key, as the work unit depends on this and conditions progress. To this end, coordination in decision making, planimetry production, financial management for the supply of materials, and the construction itself, which includes managing work

Figure 11. Beginning the prototype's construction. Source: Preparation by the authors.
Figure 12. Implementation of the prototype in the final location. Source: Preparation by the authors.

safety, is vital. Architecture students usually have a very vague idea of the complexity of these processes, and experiencing them allows them to get involved in their real resolution and enhances construction processes, compared to the design processes they are more familiar with.

In addition, the construction process forces them to delve into the constructive design of the project and make decisions they are not normally forced to make. Facing a worksite requires designing by deciding on a larger scale than usual, and solving problems that occur during the construction process (Figure 12) that, probably, in purely academic projects, would be discarded as "irrelevant". This also requires defining and producing a very detailed and clearly expressed planimetry for its use by third parties, who may not be designers or students.

This resolutive overexertion provides them with a remarkable capacity for reaction and work. Team management and the use of its maximum potential by combining efforts (Figure 13) is, perhaps, one of the most valuable lessons that can be acquired, although it is not simple and should be based on the simultaneity of integrated knowledge learning (Domingo Santos, 2010). Students are normally used to working in groups, next to each other, but in a sequential, non-integrated way, which is necessary when approaching collaboration from a holistic approach. An integrated prototype design for the Solar Decathlon competition requires and promotes holistic versus sequential and even traditional collaboration in the peer-to-peer architectural profession (whether architects or engineers), in charge of different aspects of a project (structures, construction, installations), just as Chiuini *et al.* (2013) state. The experience that this competition entails during the construction phase, in this sense, is of great importance, albeit basic, due to the limited maturation times for the team, which would always demand more opportunities for collective and cooperative learning.

Figure 13. Completion of the prototype in Hungary.Source: Preparation by the authors.

This methodological approach is a pedagogical experiment like the one developed in Amereida, Open City, Chile (Millán-Millán, 2019), which starts from the methodological principles of Bauhaus and combines theoretical conceptual reflection and the real practice of the architectural project. The constructive experience is considered a life experience, not just an educational one, because of its implications in the person's training and not only in that of the technician. When students face the priority, urgent, and rigorous technical issues involved in building a prototype, from a decision-making process that many must agree upon - not decided by teachers or a particular student -, the constructive exercise entails a collaborative life experience (Figure 13).

The work is accompanied by numerous planimetry adapted to each phase of the construction process. The models (Figure 14) are also a fundamental tool in the project's incremental development, adapting in scale to decision-making from the urban, architectural, and, subsequently, the constructive fields. The prototype is mostly made in

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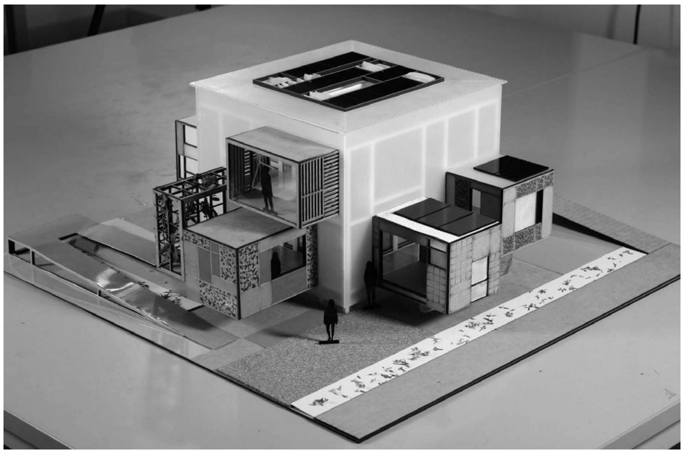

Figure 14. Solar Decathlon Europe prototype model. University of Seville team (2019). Source: Preparation by the authors.

Seville and then moved to the competition site, where its manufacture is finished. This in-depth collaborative research process, that starts from the design and acquires meaning with the construction by the students, is an educational experience rarely reproduced in all its experiential complexity at the School of Architecture of Seville.

The AURA 3.1 prototype was developed for the Solar Decathlon Europe 2019 competition (Herrera-Limones et al., 2021). The project, which we call the AURA Strategy, was based on a sustainable construction strategy for the urban regeneration of obsolete residential neighborhoods, through the reuse of existing buildings, while taking into account the Mediterranean climate. The neighborhood of the San Pablo Industrial Estate in Seville (Spain) was chosen as a case study for the project's urban application.

The effectiveness of the proposal in terms of sustainability was demonstrated by the results of the competition. It obtained the first two prizes in the quantitative tests, based on the onsite measurements collected with sensors installed on the prototype: Comfort and Operating Conditions of the House (Alonso, Calama, Suárez, León & Hernández, 2022). In addition, it won a third prize in the Sustainability competition, which proves the enormous possibilities that the AURA Strategy has in the field of sustainable urban regeneration and bioclimatic behavior in social housing retrofitting.

The main regenerative action applied consisted in the juxtaposition, on a social housing block, of a technological-structural system that provides new technological and spatial features. This prefabricated system is composed of a connecting envelope and expansion modules with the following features: a fragmented system that allows a more generalized application on a greater number of housing units and the ability to adapt to the specific requirements of each building/dwelling; a progressive system that does not require a full building to be operational; a system compatible with the use of the building during the construction process; and a system open to the incorporation of future needs.

The achievements obtained in the competition have allowed continuing with perfecting the possibilities of the proposal, through the research project entitled "Direct application of the *Aura Strategy* of the U.S. Solar Decathlon Team, in the rehabilitation of obsolete Andalusian slums", funded by the Junta de Andalucía (Spain) and currently under development.

CONCLUSION

The validity of the process compared to the pure finalist nature of this type of teaching project strategy, the wealth of the countless borderline situations raised on the road, as well as two-way learning between professors and students, make this type of experience an excellent teaching tool in the field of the sustainable social habitat, given that the bioclimatic aspects of ideation, project, and prototype implementation are especially valuable.

This unique form of research (using project instruments and architectural construction with a prototype specifically conceived for each case in question) requires previous theoretical inquiry about what the new types of more sustainable construction systems and the most environmentally efficient housing solutions could be.

In short, the educational methodology used is confirmed as strategic for obtaining timely results that train the student within a sustainability framework. The active methodology of project-based learning has the student face a specific problem, supported by their professors and the existing doctrinal body on the subject, but one which they need to address together with their peers, in a proactive, coordinated, and resolutive way.

Thus, the strategy of building a prototype and not just its design with bioclimatic criteria is an added challenge, as it involves aspects of the architectural area (especially development and construction logistics) that go beyond the project itself, and that are linked to its physical concretion, an experience that students do not usually face. From that perspective, the achievements obtained in terms of bioclimatic design efficiency (proven by the prizes won, and not just for the simulations made), materialization, and final construction (real constructive definition), but also in the approach to a complex reality (organizational and logistical feasibility), are multiple.

Specifically, the Solar Decathlon competition has become the ideal framework for this educational experiment of incorporating sustainability aspects. (Chiuini et al., 2013) thanks to its specific requirements. The students, decathletes for the competition, together with the professors and researchers who mentor and support them, have formed a design and construction team that experiences the educational process through the project work and problem-solving methodology. The University of Seville, which has been taking part assiduously in the competition since 2010, has closed (for the moment) its participation in this type of competition with the 'Aura 3.1' project, built in Budapest, Hungary, in July 2019, in the last edition held in Europe.

The results obtained allow confirming that the educational approach and methodology employed are suitable for incorporating sustainability issues in architecture teaching, not only from a theoretical point of view but also from a practical one. Indeed, the entire project represents a significant advance in knowledge transfer, but above all, skills and abilities for architecture students. This is complemented by other types of teamwork skills, which although not specifically architectural, do strengthen aspects of sustainability linked to cooperation and collaboration, essential in its social sphere.

The active methodological dynamic, based on project solving, was adapted to the corresponding times and management, posing the different phases of progress in the design as problems to be solved among participating students, from the different subjects involved in the research project. In this way, the professors acted as mentors of the students' research, helping to define the objectives and goals to be achieved.

The participation of students from different areas (architects, engineers, journalists, communicators, translators) constituted a complex management factor, but a clear learning improvement. It made it possible to holistically address the challenges defined by the competition from the global aspect, confirming the complexity of the architectural-constructive process, beyond the architectural area itself, and providing students with an experiential approach to this reality, that will sharpen their collaborative capacity. In the same way, the experience became a transversal experiment (Masseck, 2017) within architecture, where the need to work on the constructive complexity of a project beyond its design and formal resolution becomes clear. With this, it was possible to introduce students to the integrated dynamics involved in the constructive definition of a built project (Alba Dorado, 2019), which meant them physically facing the need to constructively materialize a design (Fernández Saiz, 2016), and ensure its correct final operation.

However, the methodological dynamic, which in its approach has been confirmed to be suitable and very productive, has lacked rigor in its application and there is potential room for improvement. Some improvement proposals should focus on greater involvement of students in the leadership and management of the process itself. It is possible and desirable that they take on greater responsibility in decision-making, not only in the design but in its management and the prototype's construction process. It is also necessary to work on involving more students by better dissemination of activities within the university. Numerous areas, that did not take part, can be brought into the project and enrich it as a collective educational experience.

On the part of academia, it is essential to make an effort from academic management that allows student participation without impairing their productivity and academic results in the subjects of the different courses. The learning that the experience of participating in this type of competition provides, does not increase the student's academic rigor, but simply varies the methodology of acquiring knowledge, that must be fully and clearly recognized by the different subjects involved. From this approach, it is necessary to define evaluation tools that allow assessing the knowledge acquired by each one of the participating students, so that the experience constitutes a possible educational path linked to obtaining a degree in architecture or even opening the door to a master's degree program.

This experience undoubtedly highlights the educational capacity that a prototype design and physical construction process can mean for a student. Contact with the constructive reality contributes to accelerating the architectural maturation process and taking onboard the knowledge they acquire linked to each architectural area. The methodology involved allows experiencing collaborative and cooperative processes that their future work will demand, and to get to know their potentialities and weaknesses in terms of team management, working with peers, and with other areas. Today, all these skills are key for professional architectural work, so the strategy implemented is considered a success.

Finally, the incorporation of the sustainability paradigm in architecture teaching finds, in this experience, a solid basis for development that concretizes the efforts previously made by the School of Architecture of Seville. Its environmental path, which began with the Bioclimatic Architecture Workshop, is now crystalized with this kind of experience, supported by a line of research in sustainable habitat involving numerous groups, which is responsible, in turn, for ensuring the connection between the different areas that sustainability has brought together in recent years, given the urgency of climate change and the Framework of the Sustainable Development Goals.

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