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RESEARCH ARTICLE

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Architecture learning environments: Pedagogy and space in the Universitat Politècnica de Catalunya's Sant Cugat Campus

Joan Moreno | **Jordi Franquesa**

Town Planning Department, Escola Tècnica Superior d'Arquitectura de Barcelona (ETSAB), Universitat Politècnica de Catalunya (UPC), Barcelona, Spain

Correspondence
Jordi Franquesa, Town Planning Department, Escola Tècnica Superior d'Arquitectura de Barcelona (ETSAB), Universitat Politècnica de Catalunya (UPC), Avda Diagonal 649, 4a planta, 08028 Barcelona, Spain.
Email: jordi.franquesa@upc.edu

Abstract

The qualitative improvement of learning spaces in higher education has often been linked to the technicalization of classrooms, and to the dissolution of the physical and temporal framework of teaching. The main objective of this research was to examine the relationship between learning and space, beyond its formal and functional values, and how this relationship contributes to promoting an efficient, cohesive educational community that strengthens links with the society that it aspires to serve. Methodologically, a quantitative approach to the design of learning spaces is proposed in relation to three aspects: formal diversity, functional flexibility, and sociability of the university community. The proposed methodology was applied to the Universitat Politècnica de Catalunya's Sant Cugat Campus, which is recognized for the innovative nature of its pedagogical model, based on project-based learning, and the adaptation of learning spaces to educational projects. With an educational model that tends to the spatial–temporal dissolution of learning and university spaces designed under the principles of form and function, improvement in the quality of learning is related to the improvement and quality of learning spaces using the principles of functional flexibility, spatial diversity, and sociability.

KEYWORDS

architecture, higher education, learning spaces, pedagogy

1 | INTRODUCTION

1.1 | Research motivation

In the last 5 years, satisfaction surveys carried out on undergraduate students in architecture at the Universitat Politècnica de Catalunya (UPC) have shown a high level of dissatisfaction with the quality of learning spaces in the Barcelona School of Architecture (Escola Tècnica Superior d'Arquitectura de Barcelona, ETSAB) and the Vallès School of Architecture (Escuela Técnica Superior de Arquitectura del Vallès, ETSAV) (Figures 1 and 2). The teaching of architecture has traditionally been at the forefront of pedagogical innovation and its spaces have not always kept up with the dynamism of these studies.

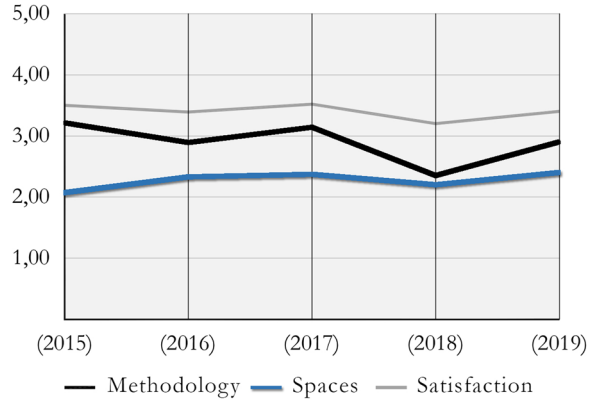

FIGURE 1 Evolution of satisfaction of Escola Tècnica Superior d'Arquitectura de Barcelona (ETSAB) undergraduate students. *Source*: Compiled by authors, based on Report of results of Graduates satisfaction survey, Gabinet de Planificació, Avaluació i Qualitat.

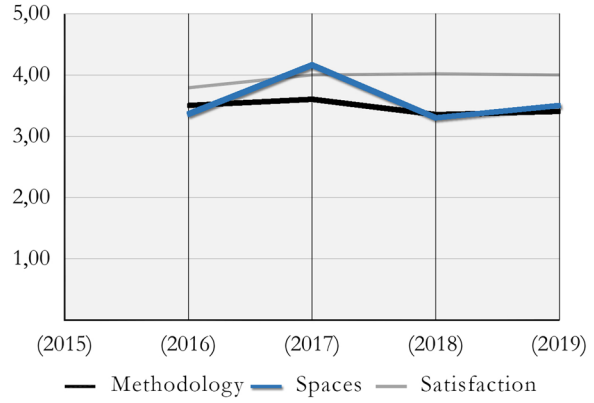

FIGURE 2 Evolution of satisfaction of Escuela Técnica Superior de Arquitectura del Vallès (ETSAV) undergraduate students. *Source*: Compiled by authors, based on Report of results of Graduates satisfaction survey, Gabinet de Planificació, Avaluació i Qualitat.

According to data collected in satisfaction surveys administered to undergraduate students in Architecture in the period 2014–2019 at ETSAB, the satisfaction with learning spaces is 0.61 points below the assessment of the school's teaching methodology (2.88) and 1.13 points below the overall satisfaction with the studies (3.4). These data show that undergraduate students recognize as positive the pedagogical methodologies used in their training as architects, but the spaces where these methodologies are put into practice (2.27 out of 5 in the overall assessment) are not considered appropriate.

The results of surveys at ETSAV show that there is a more balanced relationship between the assessment of pedagogical methodologies (3.46) and physical learning spaces (3.58), and this has a positive impact on the overall assessment of studies at the school (3.95). These results could corroborate the thesis that physical learning spaces suitable for pedagogical methodologies can contribute to an improvement in the quality of learning as a whole.

1.2 | Objectives

The main objective of this research was to examine the relationship between pedagogical methodologies and learning spaces for architecture beyond its formal and functional values. The study also evaluated how the relationship between pedagogy and architectural space contributes to promoting a cohesive educational community, based on the principles of spatial diversity and functional flexibility.

The following secondary objectives of the research were proposed:

- Evaluate the diversity of architecture learning spaces at the UPC-BarcelonaTech based on spatial configuration and technological equipment.
- Evaluate the functional flexibility of learning spaces for architecture from the distribution of activities in campus buildings and the configuration of the spaces, in accordance with the pedagogical model that is focused on either traditional education or autonomous learning.
- Evaluate the opportunity for socialization provided by learning spaces for architecture through an analysis of the inclusive nature of the spaces and the possibility of hosting innovative collective learning experiences, especially in the campus's outdoor spaces.

2 | THEORETICAL FRAMEWORK AND METHOD

2.1 | Introduction and method

The debate on learning spaces goes beyond the limits of teaching in higher education to question the spatial configuration of classrooms from the earliest stages of training [1, 6, 13, 17, 18]. The approach to learning spaces in higher education, and in particular in the bachelor's degree in architecture, is one of the main novelties presented in this article.

In the learning of architecture and urban planning, there are some examples of past experiences in which the design of space has played a dynamic role in the learning process. One of these is the Bauhaus in Dessau between 1918 and 1933 [13]. Pedagogical innovation in architectural and urban planning studies has been a constant that has allowed curricular adaptation of architectural studies

to the reality of professional practice, based on project-based learning. The Beaux-Arts Academy in Paris adopted this approach and had atelier classrooms with a certain flexibility in their composition and use. Furthermore, there is a direct relationship between learning architecture and body awareness in space [18], so the learning space is another element in the process, like the content of a subject [1].

This study begins with a bibliographic review that identifies scientific documents that address the relationship between pedagogy and the design of space in higher education in a generic way. The approach to the design of learning spaces in architecture is based on three criteria: formal diversity, functional flexibility, and sociability of the university community (Figure 3). These aspects were evaluated by measuring the degree of collective–individual, interior–exterior, and technological–analogical aspects with respect to form; circulation–stay, specialized–hybrid, and student–professor-centered aspects in relation to function; and spatial limits and the diversity of spaces in relation to sociability.

Subsequently, a taxonomy of learning spaces in higher education was drawn up based on spatial design principles. Spaces were grouped into antagonistic pairs, taking as a model the BK City of Architecture in Delft, which was then applied to the Sant Cugat Campus ETSAV to draw conclusions.

2.2 | Formal/informal learning environments

Traditionally, pedagogical innovation in higher education has been associated with the technicalization of learning spaces [12] (Figure 4). Despite improvement in

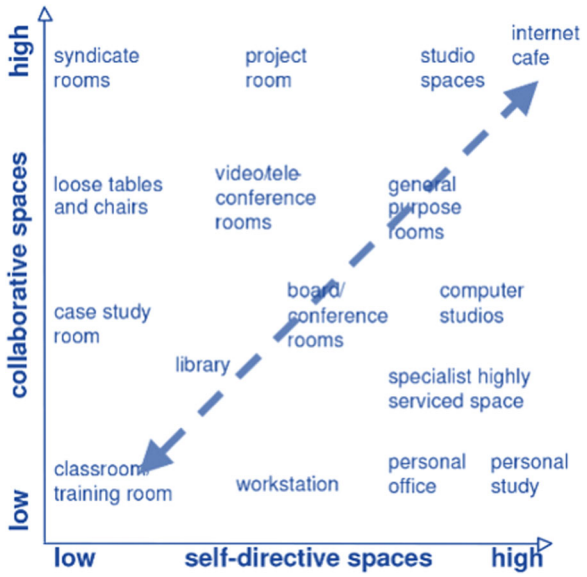

FIGURE 4 Matrix of collaborative or autonomous learning media. *Source*: Fisher and Cleveland [12].

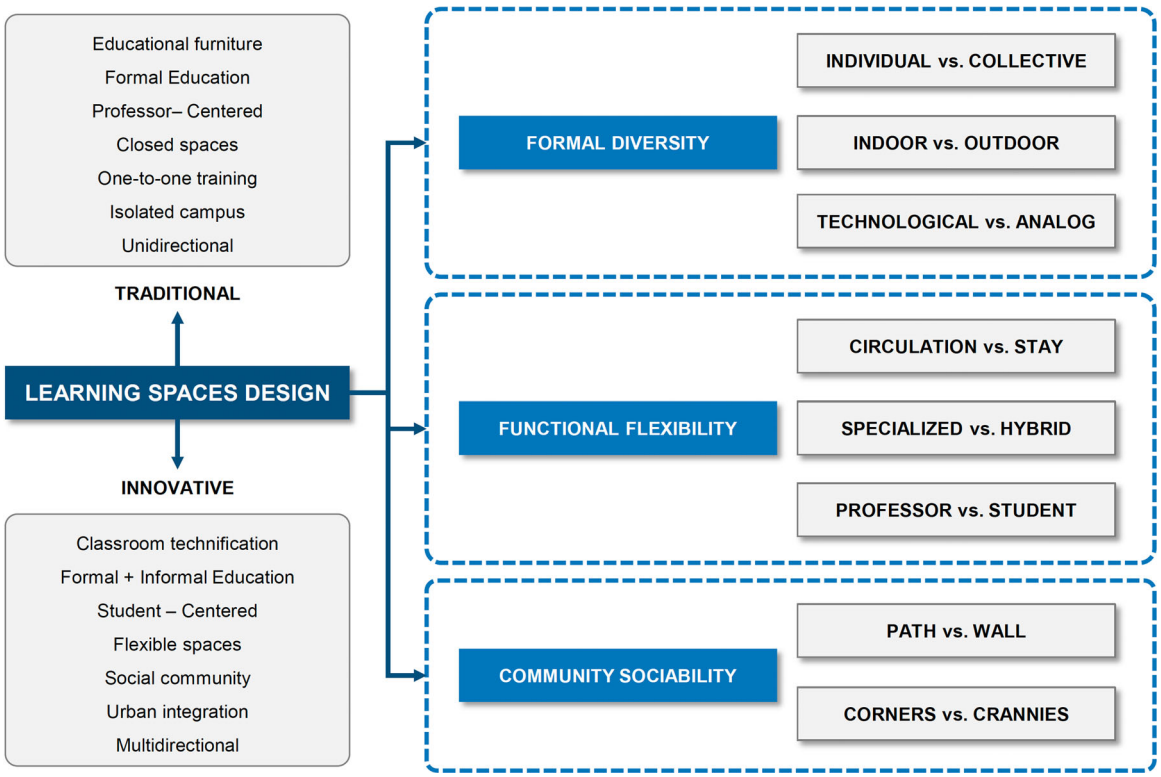

FIGURE 3 Conceptual map of the methodological framework. *Source*: Compiled by authors.

classrooms' digital equipment, the technology applied to the classroom has not led to a review of pedagogical methodologies and the traditional top-down model has been maintained, in most cases. Even so, good learning is based on the optimal relationship between pedagogical practices and the design of formal and informal teaching spaces [10].

In architects' training, learning is not only acquired in the classroom and not just on the university campus. Instead, it forms part of students' life experiences and the catalog of spaces perceived during their training. Learning is therefore a global experience [5] that goes beyond the physical classroom and formal education. In addition to this learning based on the sensory perception of space, new virtual environments are gaining prominence in training and are outside the regulated learning of educational centers.

Online education has led to a turning point in the relationship between students and teachers and the flexibility of formal–informal learning environments. Student training requires a combination of skills acquired through formal and informal systems, which means that spaces are needed where students can take control of their own studies [16].

At this point, we should distinguish between formal learning spaces and informal ones. Formal learning spaces are used for classes scheduled on a regular basis in accordance with a pre-established program. Five categories of formal learning spaces can be distinguished:

- *Traditional classroom*: The division between the front and the back of the classroom is clearly defined (one-way teacher–student relationship).
- *Conference room*: The space is similar to the traditional classroom but with greater capacity (stepped auditorium).
- *Equipped classroom*: The space has technological facilities such as computers, digital projectors, screens, and internet access.
- *Laboratory*: This is a space with formal equipment, which is usually fixed, and technical instrumentation to undertake experiments or for design, depending on the discipline.
- *Active learning classroom*: This is a space that includes mobile furniture, easily accessible plugs, ports, mobile screens, and video projectors. These classrooms are designed in a multidirectional way without a front and a back. They promote collaboration between students and the implementation of mixed, student-centered teaching methodologies.

Informal learning could be defined as extracurricular, open, individual learning that does not follow a linear structure. This type of learning is based on the achievement of learning objectives and intrinsic motivation, instead of execution objectives or extrinsic motivation [11]. Traditionally, the learning that takes place within schools is considered to be formal and that which takes place outside is informal [15]. However, some pedagogical models defend the incorporation of informal learning into university spaces.

One of these models is conceived by the university as a "market square" [2]. This theory is against formal learning based on spatial centralization, restrictive access criteria, and rigid bureaucratic procedures that put learning opportunities at risk. In accordance with these principles, the university becomes an open space in which the student "circulates" through the spaces and can examine the products offered by the teachers before accepting them. This vision questions the formal education model as:

- Anyone can access the courses offered in a public training catalog, without limitations of registration or previous training.
- Anyone can become a teacher as long as the subject of their course can attract the interest of potential students.

The combination of formal and informal learning is not a new phenomenon in university education. In fact, libraries and study rooms have traditionally used this learning model, which is closer to the interests of students.

2.3 | Teaching architecture: Form and function

The design of spaces according to the principles of functionality and efficiency is part of architects' academic training. The relationship between the shape and function of a space is one of the paradigms of modern architecture. These constraints have forced a functionalist vision of architecture in which a one-way relationship has been established between form and function, but where flexibility has been entrusted to the dimension and distribution of furniture in a space.

When we talk about learning spaces, we refer to all the spaces in which the university educational experience can take place. In the configuration of these spaces, the actors and inductors should be differentiated [7]. The actors are all the people or physical spaces, including urban and natural ones, that influence learning. The physical spaces correspond to the shape of the architecture. In contrast, the inductors are all the elements that

contribute to indirectly stimulating learning that include elements of furniture and technology.

2.4 | Shape of space (diversity)

From a formal perspective, the classroom is a space confined by four vertical and two horizontal surfaces in which learning occurs according to an established schedule that is opaque and one way. In this traditional spatial conception, there are physical and temporal limits. However, educational architecture should transcend this view of a container [8]. Currently, the space–time limits are laxer, so learning can occur anywhere and at any time. The configuration of formal learning spaces is based on classrooms oriented toward a stage with the aim of transmitting knowledge and treating students as passive consumers [16]. These spaces do not favor interaction between students.

Therefore, learning cannot be disassociated from the physical and spatial conditions in which it occurs, even if it occurs partially through virtual platforms. Often, the design of these spaces is not based on pedagogical criteria but on other variables such as economic or fire safety.

2.5 | Function of space (flexibility)

Although some spaces have a suitable design to induce certain behavior in users, these behaviors are not always considered initially. The objective should be to offer the opportunity for activities to take place through the design of the space [3]. In fact, the opportunity provided by learning spaces has often been evaluated once they have been built, without the possibility of establishing spaces for participation or debate between teaching teams, research groups, students, and space designers.

Usually, the economic investment made in the construction of learning spaces is amortized within approximately 50 or 75 years, so their formalization will affect future pedagogical methodologies [4].

In the 1990s, the concept of fused-use environments was introduced based on the design of spaces that could host a range of activities but also had the ability to integrate the physical and virtual environment. Pedagogical innovation in higher education directly affects the configuration of learning spaces, with a shift from a traditional monofunctional model to a combination of formality and informality. Traditionally, this role was played by spaces such as the library or the study room [9].

Flexibility is, therefore, one of the basic principles of the spatial design of teaching spaces, especially considering the changing dynamics of learning processes.

2.6 | Architecture and environment (sociability)

One of the objectives of universities, as educational centers, is to train professionals who are committed to solving the social problems of their time. However, this social commitment and knowledge of reality are not possible without human interaction, and social contact must occur in a suitable physical space.

Beyond their shape and function, training spaces are areas for human interaction [7]. In other words, the creation of quality learning spaces can contribute to an improvement in training processes and the motivation of students, and the feeling of belonging to a social community: the university. Consequently, new educational architectural typologies are emerging based on patterns of human interaction rather than the specific spatial needs of pedagogical models [14].

The three basic principles of spatial design to promote sociability are given below:

- *Spaces must be planned on four scales*: City, campus, building, and classroom. The dissolution between these scales leads to a succession of spaces that provide different environments and possible uses.
- The human scale should be the guiding thread in the design of learning spaces. Humans establish affective relationships with other members of the community and material elements. Incorporating the human scale implies considering the movement of the body through space in a guided or drifting way.
- The creation of an experiential learning community is essential for the integral training of the individual. This implies the need to understand the university as a habitat [20], that is, a space for organized coexistence formed by a community of people who carry out varied, interacting activities.

The design of learning spaces as areas for sociability cannot be limited to the educational building but should consider the set of spaces on campus and the city that can complement students' training.

3 | A MODEL: BK CITY-TU DELFT

On May 13, 2008, a short circuit caused a fire that devastated the Delft Technology University (TU Delft) Faculty of Architecture building. The historic building had been designed by the community of architects van den Broek and Bakema in 1970, in accordance with the functional and aesthetic principles of postwar Dutch structuralism (Figure 5).

FIGURE 5 Hall of the Faculty of Architecture of Delft Technology University as a meeting place. *Source*: Netherlands Architecture Institute Collection (Rotterdam).

With the remains of the old building still smoking, the director of the architecture school, Professor Wytze Patijn, had already convened a crisis cabinet to move the architecture to the campus's main building, which was unoccupied at the time. The new school provided an opportunity to implement pedagogical reform and introduce new spaces. In a first intervention, the partition walls in the departments were removed to favor the creation of shared workspaces between teachers, and the lobby was enabled as a workspace for students.

3.1 | New spatial and educational project

The configuration of spaces in the new architecture building initiated an academic debate on the future of learning in architecture studies between the educational team, the community of students, and the administrative staff. It was a laboratory to experiment on the relationships between spaces and relationships with the educational community.

The project had to accommodate a total of 1400 undergraduate students, 1700 postgraduate students, and 850 staff of the school, in a useful area that was 25% smaller than the old building. The challenge was mainly focused on flexibility, diversity, and public space. Given the smaller useful area of the new building, a more efficient use of the space was proposed (Figures 6 and 7).

FIGURE 6 View of the BK City-Delft Technology University model room. *Source*: BK City (2020).

FIGURE 7 View of the diaphanous and multifunctional work room. *Source*: BK City (2020).

Regarding the concept of flexibility applied to the use of faculty spaces and furniture, common spaces such as conference and seminar rooms can be adapted to different uses. The library is not only a document storage space but also offers more than 100 extra workspaces. Another concept is diversity: the creation of a wide variety of spaces with adequate quality standards to accommodate users and diverse activities. The creation of these spaces with their own identity also reinforces the feeling of belonging between the faculty's social community and the spaces it occupies.

Finally, the functional program is arranged around an interior street that is 150 m long and functions as a backbone connecting the main common spaces in the entire architectural complex.

3.2 | The Why Factory Tribune

The Why Factory Tribune is a research institute that moved to the eastern courtyard of the new headquarters

FIGURE 8 Why Factory. *Source*: Compiled by authors.

in Julianalaan (Figure 8). The color orange is the characteristic element of the proposal and emphasizes the autonomy of the institute with respect to the rest of the spaces of the school. The space has flexible, versatile, and mobile furniture that is connected to the electrical grid. This furniture includes chairs and tables that are grouped every eight units to favor collaborative work.

The artifact functions as a large furniture-building around which different flexible spaces of work, study, meeting, exhibition, and so on, are available. It is even used to host large events such as film screenings or exhibitions.

4 | TU DELFT ANALYSIS

The adaptation of traditional learning spaces to new pedagogical methodologies has often been confused with the extensive incorporation of technology into the classroom.

At this point, we should ask ourselves to what extent the formal learning spaces of higher education centers can be transformed to accommodate new methodologies according to the criteria of functionality and spatial quality. One example is the Pulse building of TU Delft

FIGURE 9 Central space of the Pulse building. *Source*: Delft Technology University (2020).

that is defined as "a central space that allows students and teachers to make contacts, collaborate, acquire and share knowledge" (Figure 9).

Another important question is the heritage value of educational buildings based on their architectural singularity or monumentality. Interventions on buildings classified as cultural heritage to adapt them to new teaching methodologies may include the incorporation of the infrastructure required to carry out these activities.

4.1 | Form

4.1.1 | Collective versus individual

One of the first aspects to consider in the design of learning spaces is their dimension. As a general rule, very light spaces with sufficient free height can accommodate a greater number of users and allow greater flexibility, to compartmentalize the space at times depending on needs [7] (Figure 10).

Another key aspect in the design of learning spaces is adaptation to human scale and, therefore, the relationship between the individual and the community. Schools should offer spaces that facilitate collaborative and individual learning in suitable conditions.

4.1.2 | Interior versus exterior

Students' informal learning mainly takes place outside the university classroom and incorporates a series of life experiences that contribute to the achievement of cross-disciplinary and general competences. One of the factors that contribute to enriching and motivating this learning on the university campus is the incorporation of spaces for socialization and exchange among the academic

FIGURE 10 Image of the study rooms for the degree in architecture. *Source*: Compiled by authors.

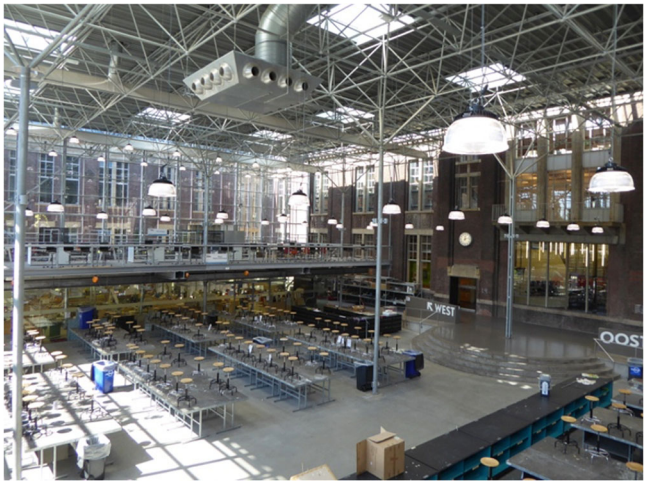

FIGURE 12 Model workshop in BK City. *Source*: Compiled by authors.

FIGURE 11 Terrace of the BK City bar-restaurant. *Source*: Delft Technology University (2020).

FIGURE 13 Backbone of the interior routes of the building. *Source*: Delft Technology University (2020).

community, that is, between students, the teaching team, and administrative staff [19] (Figure 11).

Another key concept in this model for the design of learning spaces is that of threshold or transition spaces between the formal–informal or interior–exterior spaces of university centers. "The threshold provides the key to the transition and connection between areas with different demands, such as a space that in itself essentially constitutes the spatial condition of meeting and dialog between areas of different order" [17].

4.1.3 | Technological versus analogical

New technologies applied to education do not have to replace face-to-face education in university centers (Figure 12). However, they can be a key element in the rethinking of pedagogical methodologies. At first, technology was incorporated into the teaching space without altering the pedagogical model. For example, the slide projector was replaced by the digital screen, but the pedagogical model was unchanged [6].

4.2 | Function

4.2.1 | Circulation versus room

Circulation spaces inside university centers often become spaces for interaction of the academic community where informal learning takes place. That is, a corridor with adequate comfort and equipment conditions can become a "didactic street" (Figure 13). In this case, its function goes beyond communication between formal learning spaces such as classrooms or workshops. The design of participatory spaces with elements that invite

participation such as worktables or exhibition panels can become dynamic elements for academic activity.

The objective would be to ensure that circulation spaces are also spaces for relationships and that can accommodate informal learning. Consequently, it is essential to create basic conditions of comfort and equipment that allow these activities to be conducted, such as the availability of natural light, a visual relationship with other spaces in the center, adequate furniture, electrical connection, and Wi-Fi.

4.2.2 | Specialized versus hybrid

Traditional university spaces can be classified into four categories depending on their function: transfer, research, administration, and recreation. This led to the separation of research and teaching spaces, with a focus on a teacher–student authority structure that does not promote academic collaboration in the university environment.

Faced with this specialization and separation of functions in university buildings, some spaces have assumed the role of hybrid spaces that can host different types of activities. Their flexibility has turned them into showcases of the centers' academic and social activity; for instance, lobbies in which exhibitions, presentations, and social events are held or libraries are created (Figure 14).

4.2.3 | Student/teacher

Traditionally, universities' teaching spaces have put the professor at the center of the design, in accordance with a pedagogical model in which students' learning is focused on content communication. In this context, the flexibility of spaces depended exclusively on the ability to move the furniture (Figure 15).

Student-centered learning spaces are not designed for one-way education from teacher to student. Instead, they promote collaborative learning among students through the multidirectional layout of the furniture and the opportunity to carry out various academic activities simultaneously, for example, individual consultation of digital databases, teamwork, and oral presentations of exercises.

4.3 | Sociability

4.3.1 | Way versus fence

Two aspects must be considered: limit and scale. The concept of limit can be applied in space and time and affects the size of the classroom and the relationship between the campus and the city. The physical limit between the inside and outside of learning spaces can be direct. In this case, the transition element is a "membrane" or skin (façade) or it can be an interstitial space like a lobby [8] (Figure 16).

However, some university campuses that are integrated into urban centers have incorporated public spaces and services such as cafes and libraries into their basic spatial structure. They extend the radius of academic action beyond buildings and interact with the urban social fabric. Isolated university campuses in the metropolitan periphery must provide their own basic services. This also affects the level of interaction and cohesion of the academic community.

4.3.2 | Corners versus gossip places

Traditionally, the social hubs of university buildings have been the hallways, corridors, and vertical communication

FIGURE 14 Library. *Source*: Delft Technology University (2020).

FIGURE 15 Theory-auditorium classrooms of BK City. *Source*: Delft Technology University (2020).

FIGURE 16 View of Mekelweg Avenue, the central space of the Delft Technology University (TU Delft) University Campus. *Source*: TU Delft (2020).

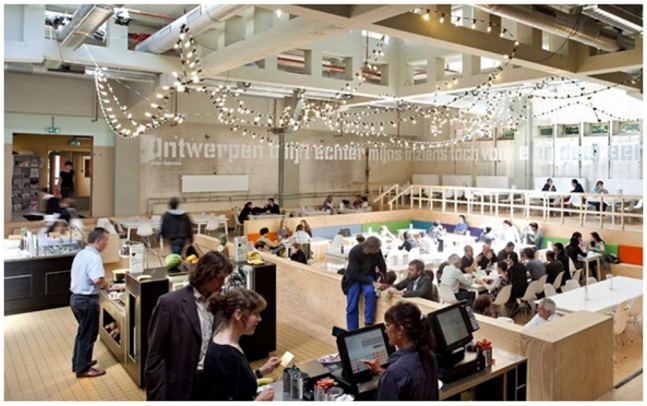

FIGURE 17 Bar-restaurant of Delft Technology University (TU Delft). *Source*: TU Delft (2020).

elements such as stairs and elevators. These spaces are true corners of the university community since chance or arranged meetings take place in them between students, teachers, and service staff, while people are entering or leaving classes.

The architecture of university centers should offer alternative and flexible spaces that complement traditional formal and rigid spaces. They could be defined as corner spaces that offer the possibility of meeting for collaborative learning activities, in contrast to gossip spaces that have a more intimate configuration and allow privacy (Figure 17).

5 | CASE STUDY: CAMPUS SANT CUGAT-UPC

The Vallès Architecture ETS was inaugurated in 1991 in Sant Cugat del Vallès, in a sector in full urban development. The current building houses in 8800 m^2 the studies of the degree in architecture (GEArq) and two master's degrees, with an academic community of 1100 students and 134 professionals, including teaching and service staff (Figure 18).

At present, the Sant Cugat Campus is one of the nine campuses that the Polytechnic University of Catalonia has distributed throughout Catalonia. It is formed exclusively by the Vallès Architecture ETS and its adjoining facilities, occupying a total area of 2.4 Ha (Tables 1 and 2). The main building is divided into two sections: the first (SC1) houses the spaces of the various departmental sections and the academic and catering service spaces, reprography, and the model workshop. The second section (SC2) is intended for academic activity and contains

FIGURE 18 Campus Sant Cugat. *Source*: Universitat Politècnica de Catalunya-BarcelonaTech (2020).

classrooms, workshops, computer labs, a library, and an assembly hall (Figure 19).

5.1 | Pedagogical model

Undergraduate studies in architecture are characterized by teaching in small groups. Every year, 100 new students are enrolled who are distributed in two autonomous groups of 50 students. The ratio of the workshop groups is 20 students per teacher. This guarantees personalized follow-up of the work undertaken by students.

One of the distinguishing features of ETSAV, from a pedagogical perspective, is the inclusion in the teaching plan of Workshops of Architecture and Projects (TAP). This subject is designed as an interdisciplinary architecture laboratory from the fourth semester of the degree. It is described as: "learning model around the project as a synthesis and confluence of the different disciplines,

TABLE 1 Table of spaces and surface areas of the Sant Cugat Campus: Building SC1.

Building SC1	m^2
Administration	281.29
Teaching team offices	869.37
Multipurpose classrooms (MU-LU-SD)	160.57
Model workshop	198.26
Laboratories "Esteve Vicens"	24.50
Porter's office	75.10
Bookshop	39.06
Bar-restaurant	223.94
Copy shop	22.59
Lobby and corridors	638.19
Services	111.12
Landings and stairs	159.29
Total	2803.28

Source: "Verifica" (degree in architecture studies).

TABLE 2 Table of spaces and surface areas of the Sant Cugat Campus: Building SC2.

Building SC2	m^2
Theory classrooms	559.77
Workshop classrooms	21,196.02
Classroom XV	56.85
Computer rooms	115.47
CC Laia	150.18
Lidia	13.00
Assembly hall	238.28
Library	439.49
Exhibition hall	447.36
Lobby and corridors	950.05
Services	139.97
Total	5269.44

Source: "Verifica" (degree in architecture studies).

guarantees the student the acquisition of skills such as teamwork."

5.2 | Types of training activities

The curriculum of the bachelor's degree in architecture defines five types of training activities (Table 3):

- *Theoretical class*: Lesson taught by the teacher that can have different formats (theory, problems, and/or general examples).
- *Practice or problem class*: Theoretical–practical class in which applications of theory, problems, exercises, and so on, are proposed and solved.
- *Computer/laboratory class*: Classes held in spaces with the necessary infrastructure with computers or specialized equipment.
- *Workshop class*: Teaching space that is characteristic of architecture teaching that allows reflection on and development of architectural problems proposed for their interest and teaching effectiveness.
- *Specialized tutorials*: Presentation, exhibition, debate, commentary, and/or orientation activities of individual works or conducted in small groups.

The training activities in the architecture curriculum at ETSAV and ETSAB are listed in Table 4. Whether they are face-to-face (P) or distance (NP) activities has an impact.

The teaching methodologies used in both centers are shown in Table 5.

6 | CAMPUS SANT CUGAT ANALYSIS

6.1 | Form I

6.1.1 | Collective versus individual

All the spaces in the center offer optimal comfort conditions for undertaking individual tasks (Figure 20). The capacity of the spaces for collective activities depends fundamentally on their surface area.

Methodologically, the size of all the spaces in the center has been evaluated, regardless of their function. As reflected in the diagram, 50% of the center's surface area is occupied by spaces larger than 75 m^2, and almost 30% have more than 200 m^2. Notably, in architecture studios, the workshops are more relevant for training students. Therefore, the availability of workshop spaces equipped with large tables is vital (Figures 21–23).

6.1.2 | Interior versus exterior

Academic architecture has its origins in monastic architecture. Consequently, historical university buildings are usually very enclosed and/or opaque towards outer public space and are organized around a system of interior courtyards such as a cloister.

FIGURE 19 Learning spaces of Campus Sant Cugat. *Source*: Compiled by authors.

TABLE 3 Table of the size of the groups for each of the formative activities.

Activity type (space)	Students
Theoretical class	60–80
Class of practices and problems	30–40
Class with computer/laboratories	15–25
Workshop class	15–25
Specialized tutorials	10–15

Source: Compiled by authors.

TABLE 4 Training activities.

Code	Training activity	
A01	Exhibition of theoretical contents with master classes	P
A02	Exhibition of theoretical contents with master classes	P
A03	Problem-solving, with the participation of students	P
A04	Oral presentation by the students	P
A05	Individual or team practical work	P
A06	Preparation of cooperative works	P
A07	Carrying out exercises and theoretical and practical projects outside the classroom	NP
A08	Study and preparation of activities	NP
A09	Raising and solving problems through autonomous work	NP
A10	Individual or team laboratory practical sessions	P
A11	Development of interdisciplinary integration and synthesis projects	NP
A12	Comparison and contrast of cases by students	P
A13	Small group discussion of specific topics based on bibliographic references	P
A14	Tutorial	P

Abbreviations: NP, distance; P, face-to-face.

Source: Compiled by authors.

In ETSAV, it is contradictory that a building located in the middle of low-density urban fabric replicates this configuration of an introspective building. Since the building does not have a central courtyard, the social life of the campus opens out toward the plot. Regarding the relationship between the inside and the outside, only 12.8% of the building has direct access to open space (Figures 24–26). This situation is partly justified by the control of access to the building. Hence, the building has a lack of permeability with respect to its surroundings.

TABLE 5 Educational methodologies of the studies of the bachelor's degree in architecture.

Code	Teaching methodologies
MD1	Exhibition method/master class
MD2	Participatory exhibition class
MD3	Seminar/workshop
MD4	Self-work
MD5	Cooperative work
MD6	Problem-based learning
MD7	Project-based learning
MD8	Case study
MD9	Tutorial
MD10	Cooperative work

Source: Compiled by authors.

6.1.3 | Technological versus analogical

Technological resources are another tool that improves communication between teachers and students and between students. They can also be used to integrate informal learning in the classroom.

In ETSAV, the level of technological equipment in classrooms depends on the presence of tools such as: Wi-Fi, an internet connection for students' laptops, electrical connection for students' laptops, data connection of teachers' equipment, PCs of teachers, PCs of students, projectors, teacher-to-projector equipment connection, interactive monitors, video playback, speakers, fixed microphones, and wireless microphones (Figures 27–29).

6.2 | Function

6.2.1 | Circulation versus room

The corridors and halls represent a high percentage of the total area and should normally be free of obstacles. Sometimes, they are ideal spaces for interaction of the university community and the visualization of activities that take place in the center.

In the case of ETSAV, almost a third of the center's surface is intended for circulation spaces (corridors, stairs, hallways, etc.), but almost half of these spaces have a suitable dimension and comfort conditions to be able to carry out formal academic activities such as workshops and presentations, as informal learning activities (Figures 30–32).

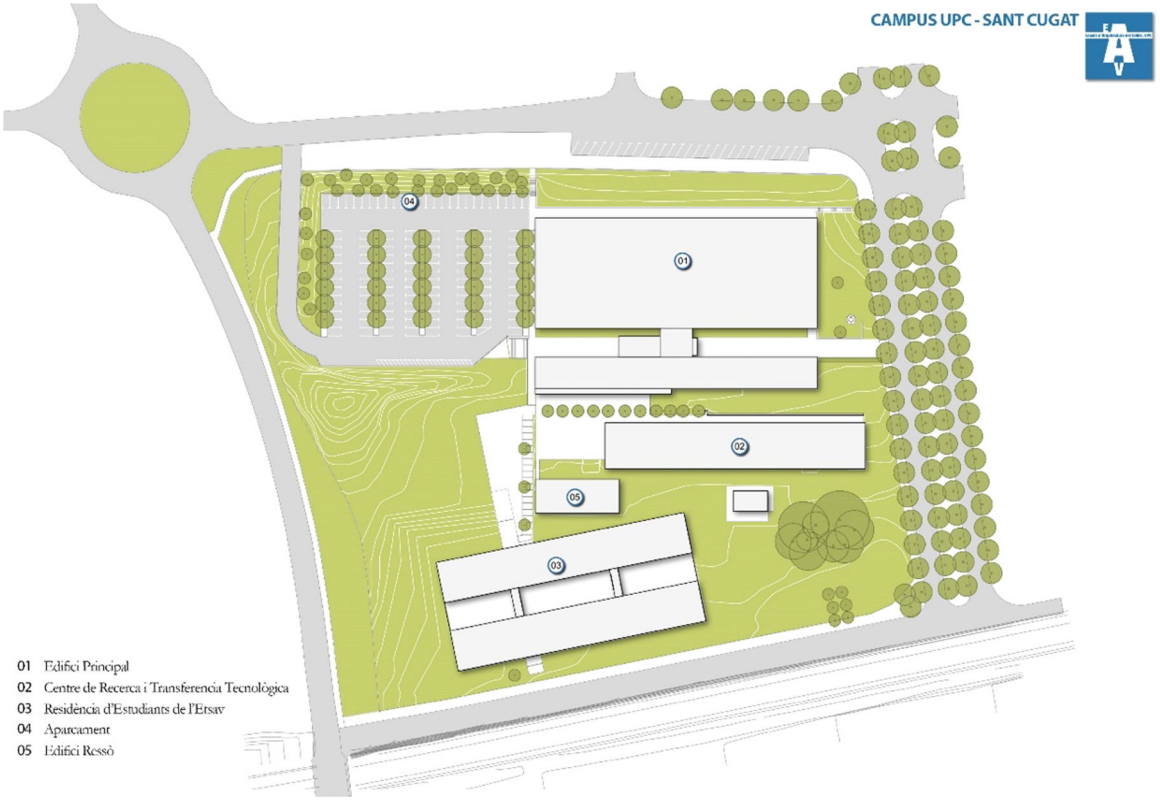

FIGURE 20 Universitat Politècnica de Catalunya-BarcelonaTech's Sant Cugat Campus. *Source*: Compiled by authors.

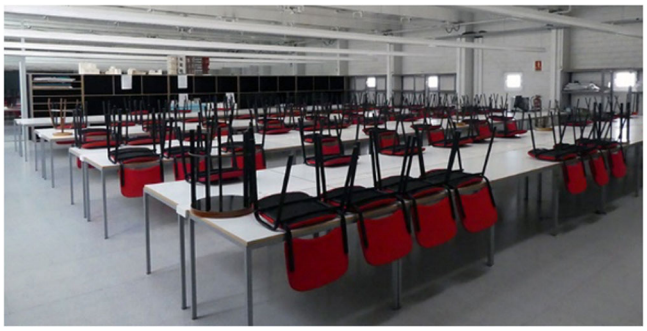

FIGURE 21 Workshop classroom. *Source*: Compiled by authors.

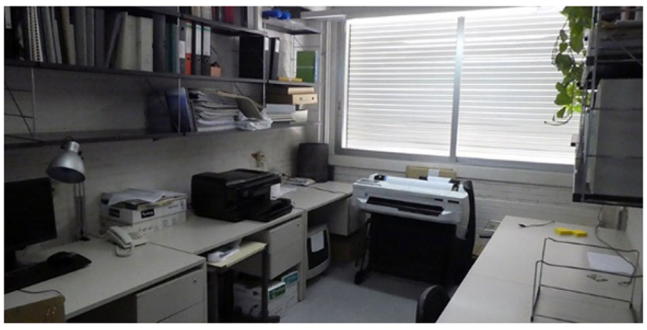

FIGURE 22 Research office in the Department of Urbanism. *Source*: Compiled by authors.

6.2.2 | Specialized versus hybrid

Normally, transfer, administration, research, and services are grouped into specialized areas in educational buildings. This spatial separation leads to a lack of interaction between teaching and research activity. This contradicts one of the objectives of higher education: the generation of knowledge from the interaction between professors-researchers and students.

At ETSAV, the first module houses functions related to the administration and management of the center, while the second module contains the theory (PB) and workshop classrooms (P1) that, as knowledge transfer spaces, occupy over 50% of the center's surface area (Figures 33–35).

6.2.3 | Student versus teacher

Traditional learning spaces focused on teaching students with rooms configured in stepped auditoriums. The new formal and informal learning methods focus on the student and promote the development of each student's skills preferably in a collaborative environment.

In the case of ETSAV, almost a third of the center's total area is configured considering the students' autonomous

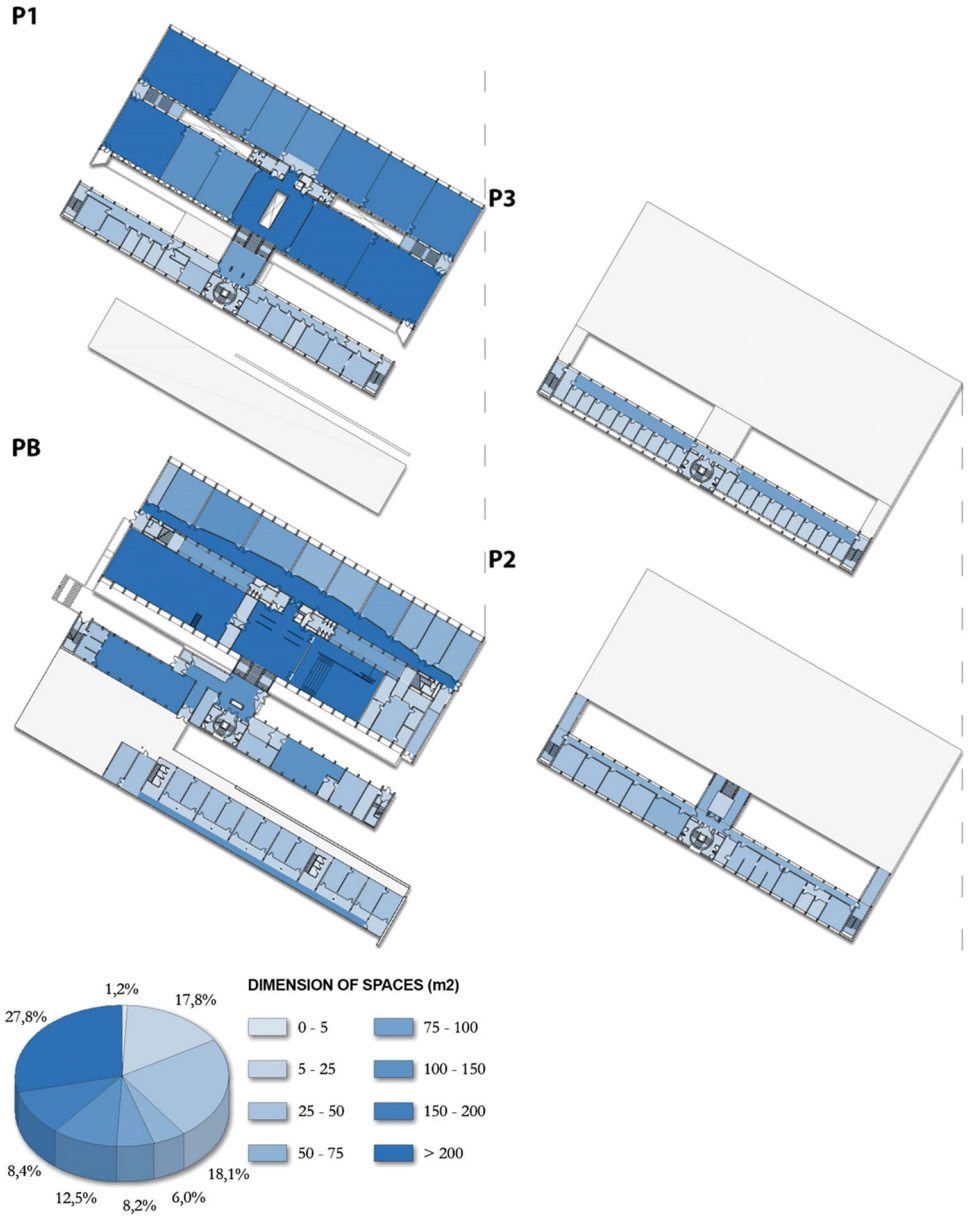

FIGURE 23 Stories and spaces of the Escuela Técnica Superior de Arquitectura del Vallès. *Source*: Compiled by authors.

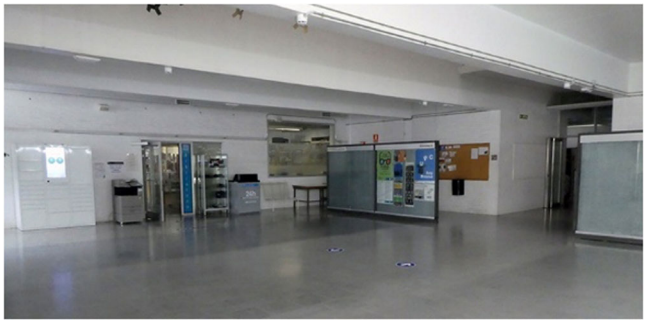

FIGURE 24 Hall of the main building. *Source*: Compiled by authors.

FIGURE 25 Terrace of the cafeteria-restaurant. *Source*: Compiled by authors.

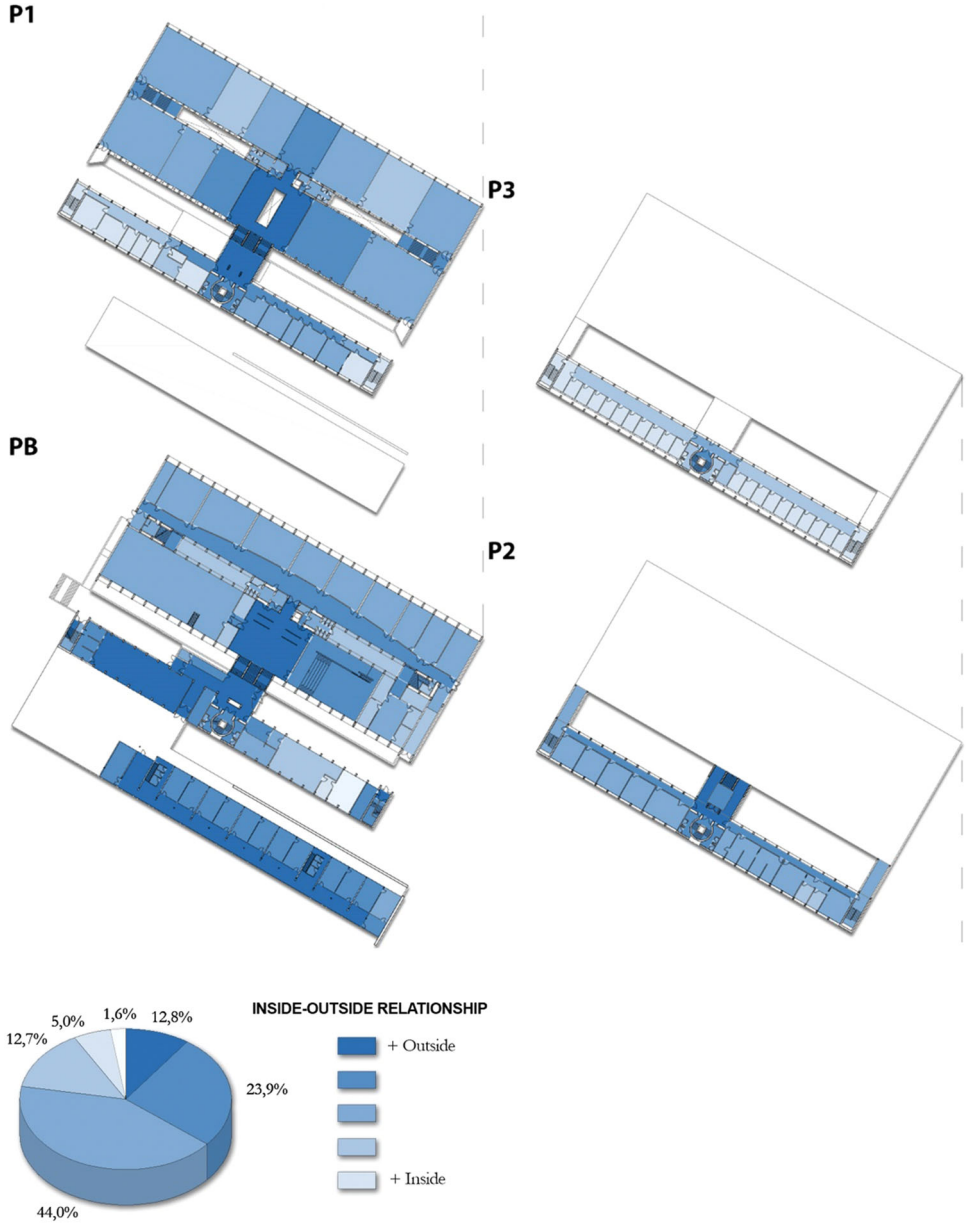

FIGURE 26 Classification of Escuela Técnica Superior de Arquitectura del Vallès spaces according to the number of them that allow access to the exterior of the building. *Source*: Compiled by authors.

FIGURE 27 Theory classroom with digital equipment in the workshop classrooms. *Source*: Compiled by authors.

FIGURE 28 Storage space for models in the workshop classrooms. *Source*: Compiled by authors.

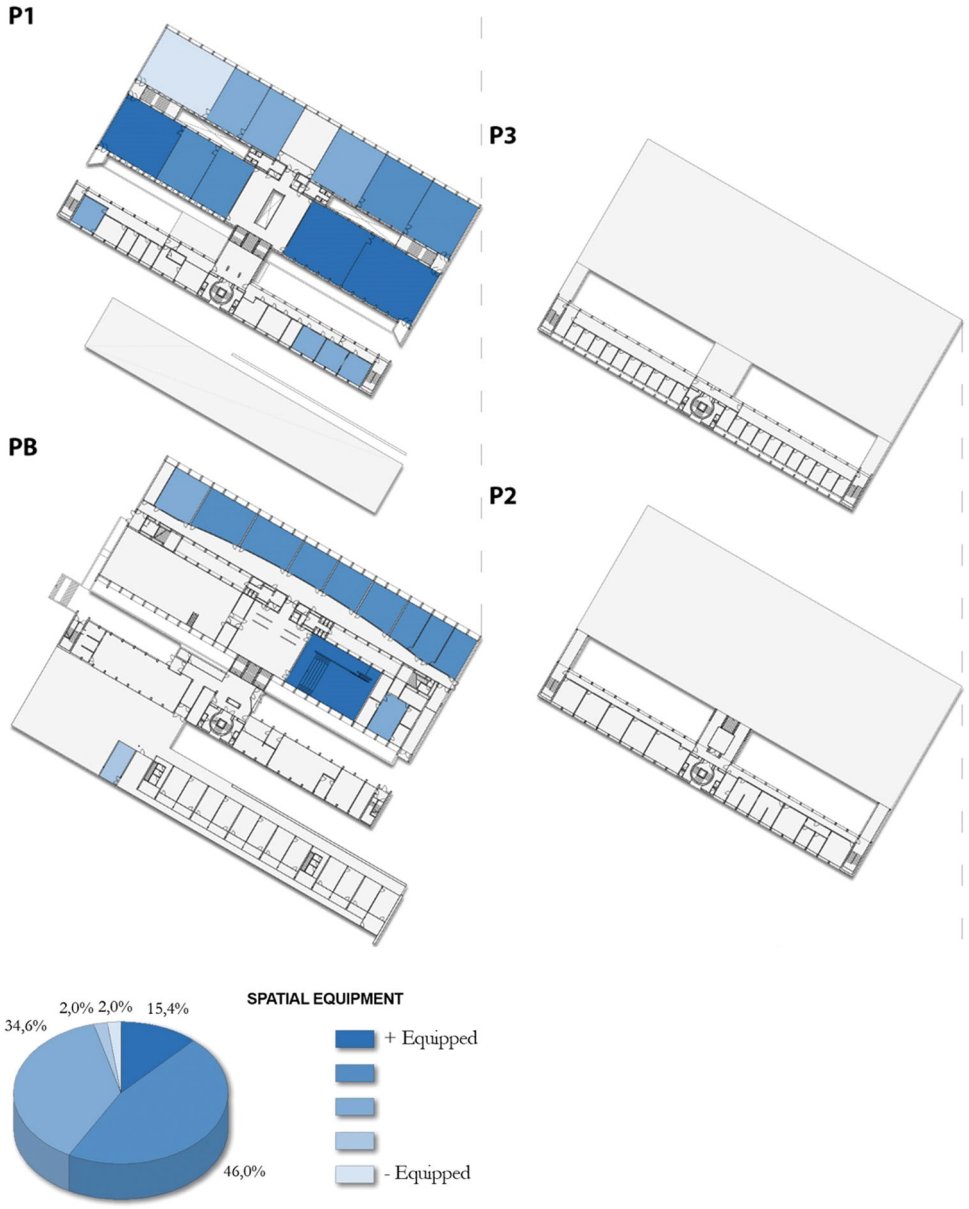

FIGURE 29 Level of digital equipment in Escuela Técnica Superior de Arquitectura del Vallès learning spaces. *Source*: Compiled by authors.

FIGURE 30 Access corridor to the theoretical classrooms with worktables. *Source*: Compiled by authors.

FIGURE 31 Theory classroom type. *Source*: Compiled by authors.

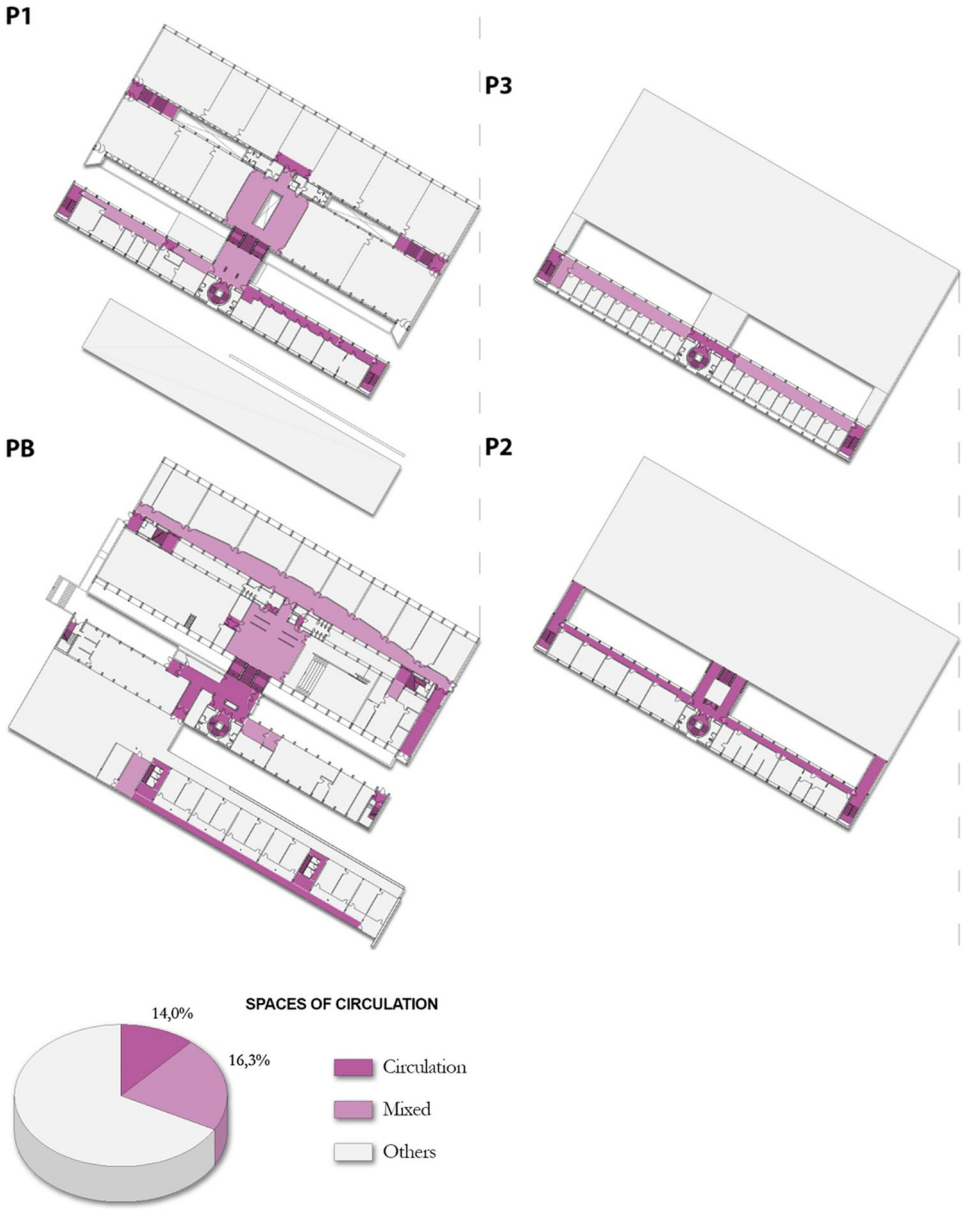

FIGURE 32 Classification of common circulation spaces according to their opportunity to host other activities. *Source*: Compiled by authors.

FIGURE 33 Escuela Técnica Superior de Arquitectura del Vallès library on the first floor where academic activities are conducted. *Source*: Compiled by authors.

FIGURE 34 Escuela Técnica Superior de Arquitectura del Vallès lobby on the first floor where academic activities are conducted. *Source*: Compiled by authors.

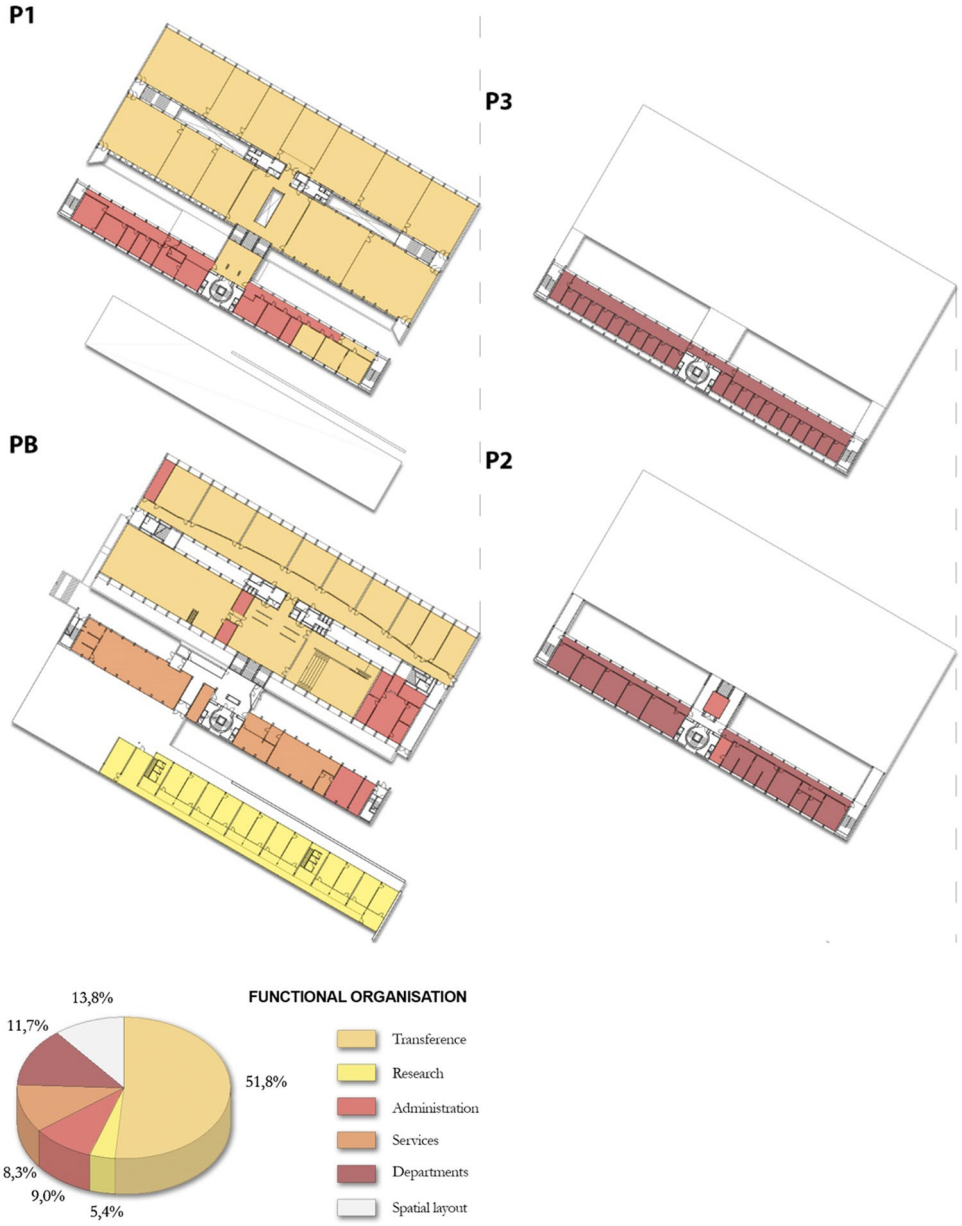

FIGURE 35 Functional distribution of Escuela Técnica Superior de Arquitectura del Vallès spaces. *Source*: Compiled by authors.

learning. This is a characteristic feature of architecture schools as students develop projects autonomously. They create plans and models in an open workshop with the weekly advice of a teaching team (Figures 26–38).

6.3 | Sociability

6.3.1 | Way versus fence

Education is a phenomenon that can only occur in optimal conditions of sociability. In other words, the skills and knowledge acquired (competences) in university centers must be put into practice in a social, spatial,

FIGURE 36 Informal space reserved for students. *Source*: Compiled by authors.

FIGURE 37 Escuela Técnica Superior de Arquitectura del Vallès auditorium. *Source*: Compiled by authors.

and temporal context. From a metaphorical and physical perspective, some elements facilitate the relationship between individuals (paths) and others pose an obstacle to interaction (fences or barriers).

In the ETSAV building, the plot is delimited by a perimeter fence that isolates the campus from the rest of the neighborhood. Considering that the school is located in a low-density district in the municipality of Sant Cugat del Vallès and that there is little catering offered in the area, many neighbors use the center's cafeteria as a meeting space. As for the interior distribution, the random layout of the modules does not contribute to clear legibility of the enclosure (Figures 39–41).

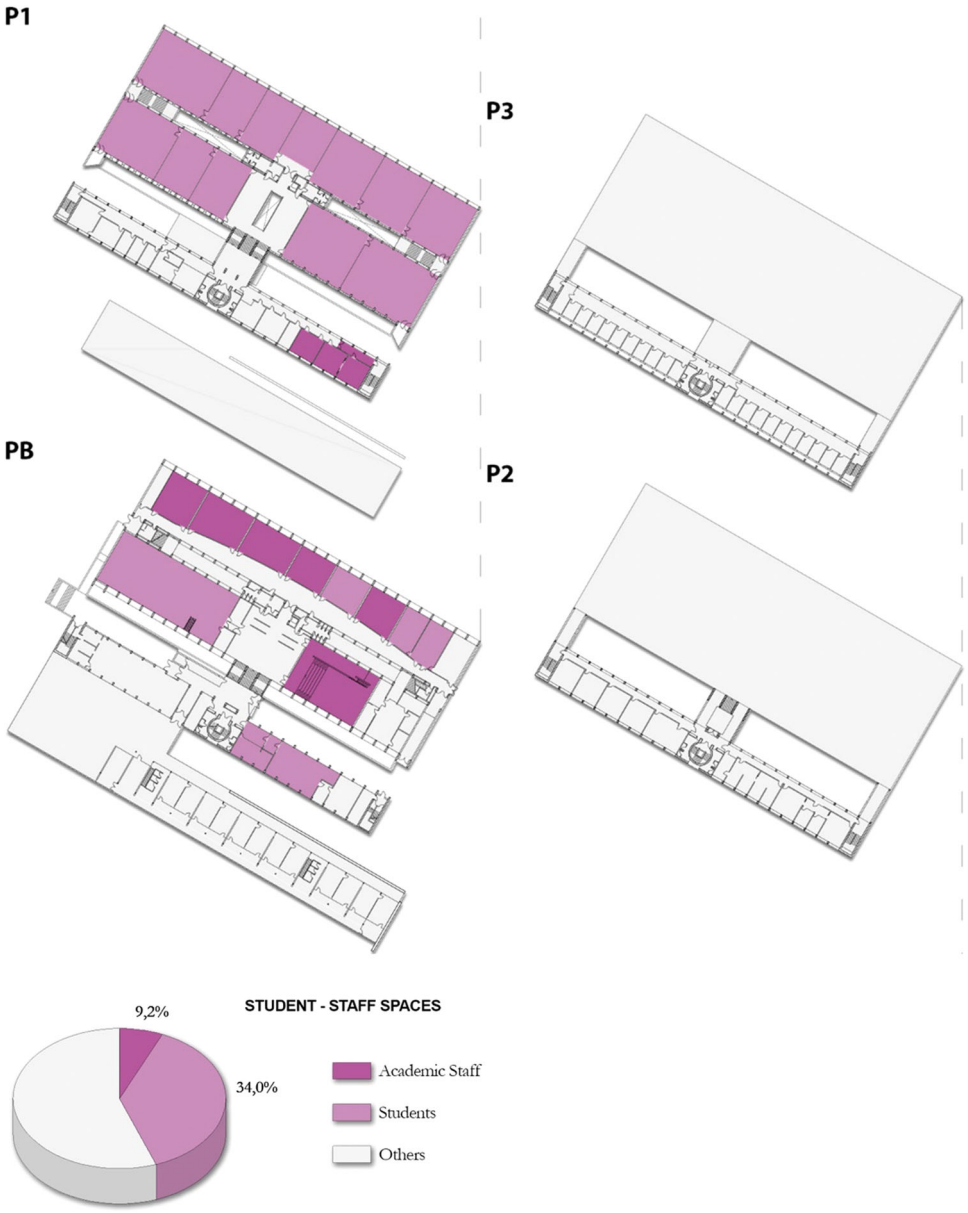

FIGURE 38 Distribution of the spaces designed with the teacher or the student as a learning center. *Source*: Compiled by authors.

FIGURE 39 Main access. *Source*: Compiled by authors.

FIGURE 40 Fence. *Source*: Compiled by authors.

6.3.2 | Corner versus gossip places

Like paths and corners, there are spaces on university campuses that provide the opportunity to experience outdoors all the knowledge and skills that have been learned in the classroom. The isolation of some university campuses such as the St Cugat Campus has allowed innovation projects to be developed physically on the site of the university itself.

One of the hallmarks of the UPC's Sant Cugat Campus is the applied and experimental pedagogical model. In recent years, ephemeral architecture projects designed with principles of environmental sustainability and energy efficiency have been tested on the grounds by the students themselves (Figures 42–44).

7 | DISCUSSION

Modern architecture has focused on the unequivocal relationship between form and function. Thus, higher education classrooms have been designed as containers [7] with the aim of controlling access, lighting, the hierarchical teacher–student relationship [16], and so on.

In relation to form, the first aspect to consider is the dimension of the spaces, which is directly related to the maximum capacity standards and the size of the groups, that is, safety and pedagogical activities. Another aspect to consider is the permeability of the learning space with respect to the external environment and the creation of thresholds [17, 19]. Often, the need to establish access controls to buildings makes the transition between the classroom and the outdoor space difficult. Finally, classroom equipment, in terms of digital and furniture elements, is vital in educational centers but does not imply a substantive change in pedagogical innovation.

In relation to the use of spaces, a distinction must be made between specialized spaces, that is, those designed to carry out a specific activity such as teaching, research, administration, and so forth, and hybrid spaces that may contain a variety of activities. Innovation in higher education implies the creation of spaces in which teaching and research meet [3]. However, new pedagogical methodologies have shifted the focus of learning from teacher to student. In the field of architecture, the configuration of workshop classrooms allows autonomous and multidirectional learning among students.

Finally, knowledge of the social and physical reality of the city is a key aspect in the training of the architect. For this reason, the spatial design of the university campus should promote interaction between society and the university community [7, 8]. This interaction can occur through the integration of the university campus into the urban fabric through the open use of its open spaces. In the case study, there is free access to a climbing wall inside the facilities and the center's cafeteria is for public use. On the other hand, the social diversity of the community is recognized through the design of meeting spaces on a human scale.

The main objective of this research was to examine the relationship between learning and space, beyond its formal and functional values, and how this relationship contributes to promoting an efficient, cohesive educational community that strengthens links with the society that it aspires to serve. The article proposes an original approach to learning from a spatial and social point of view. The article proposes the analysis of learning spaces in higher education from, on the one hand, the opportunity to promote social cohesion through the quality of the design of educational spaces for physical interaction between members of the university community. This vision represents an advance in the way of understanding the coherence between the spatial design of learning spaces and the configuration of a cohesive educational community, based on diversity, flexibility, and innovation.

FIGURE 41 Fences and access to the Sant Cugat-Universitat Politècnica de Catalunya campus site. *Source*: Compiled by authors.

FIGURE 42 Experimental module echo in the courtyard. *Source*: Compiled by authors.

FIGURE 43 Structural prototypes in the courtyard. *Source*: Compiled by authors.

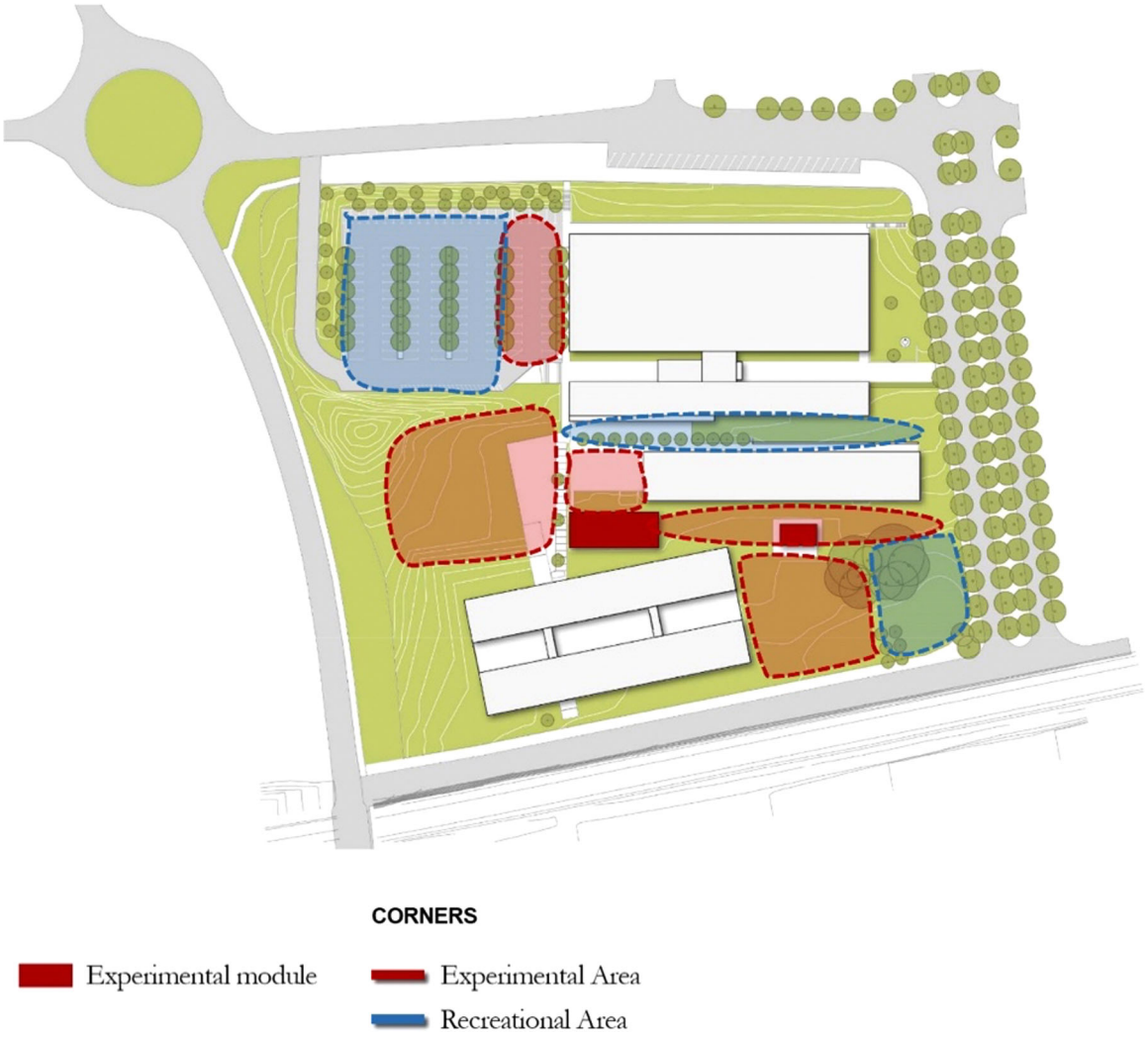

FIGURE 44 Spaces available for architectural experimentation and leisure. *Source*: Compiled by authors.

8 | CONCLUSIONS

Without face-to-face activities, learning is obviously limited. This statement could be considered reckless in the context of a health and pedagogical crisis such as the current one, but it highlights a key aspect: the aim of the university is to train competent professionals who are committed to their society and their time. Learning based only on online training prevents students from developing the social habitats that are so necessary to understand the context in which their professional activity is framed.

Therefore, if learning is a social phenomenon based on the transfer and generation of knowledge, contact between members of the academic community must occur in a suitable physical space for this communication and experimentation in conditions of efficiency and comfort. This hypothesis contradicts the idea that learning can take place anytime and anywhere. The point is not to question the opportunities provided by online synchronous or asynchronous learning but to accommodate higher education centers.

This project is proposed as a first approach to the design of spaces for learning architecture based on three principles that focus on the training of the modern architect: form, function, and human interaction. The concept of form refers to the physical characteristics of learning spaces (dimension, permeability, etc.) and their equipment (computer devices). Specialized references have an impact on the concept of spatial diversity applied to the shape of learning spaces, following the concept that the greater the diversity of spaces, the greater the opportunity to learn in different ways.

However, function is one of the key elements in the design of architecture. But how can you define the shape of a space when its function varies over time? In this sense, the key concept linked to function is flexibility, that is, that the same space can simultaneously host diverse activities over time. Often, flexibility has been

linked to the shape of the space, and a larger dimension allows for greater compartmentalization capacity. But when new ways of learning are incorporated, such as individual or collective, formal or informal, face-to-face or online, the definition of the function is diluted, and the design of the space is limited to guaranteeing the basic conditions of comfort.

Finally, the last of the aspects to be evaluated in the design of learning spaces is sociability. In this case, the scale of the university campus has been taken as a reference since the opportunity for interaction depends not only on the built spaces but also on the relationship with its urban and even natural context. University campuses are hyperspecialized spaces that remain empty during nonschool periods such as weekends or holidays. However, the services they offer and the spaces that are available could meet the needs of the urban community and not just academic ones. The tools in this case would be to blur the limits, improve connectivity and create open spaces for innovation.

In summary, based on the design of the form, function, and opportunity for socialization offered by diverse, flexible, and open spaces, we can contribute to improving the learning of future architecture professionals by integrating the pedagogical model with the spatial model of the centers, so that, as Winston Churchill said "we shape our buildings and then our buildings shape us" (House of Lords, October 28, 1943).

DATA AVAILABILITY STATEMENT

The data sets used or analyzed during the current study are available from the corresponding author upon reasonable request.

ORCID

Jordi Franquesa http://orcid.org/0000-0002-8551-3133

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AUTHOR BIOGRAPHIES

Joan Moreno is an architect with a PhD in Urbanism. His thesis "Territorial corners. Mobility and spatial planning, a model of integration: the Randstad-Holland" (2014) was awarded the Extraordinary Doctoral Award in the field of Architecture, Urbanism, and Building UPC (2017). He has a master's degree in Town Planning Research. He is a lecturer in Town Planning at ETSAB.

Jordi Franquesa is an architect with a PhD in Urbanism. His thesis "Garden communities in Catalonia. A rediscovered urban experience" (2008) was awarded the Extraordinary Doctoral Award in the field of Architecture, Urbanism, and Building UPC (2009). He has a master's degree in Town Planning Research. He is a lecturer in Town Planning at ETSAB.

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