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The Design Studio as a New Integrative and Experimental Learning Space: The Pedagogical Value of Implementing BIM, Parametric Design and Digital Fabrication in Architectural Education

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The Design Studio as a New Integrative and Experimental Learning Space: The Pedagogical Value of Implementing BIM, Parametric Design and Digital Fabrication in Architectural Education

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Abstract

In the last decades, the continuous development of digital technologies and their use in studios of architecture have redefined how the buildings are conceived, designed and produced. At the same time, these digital technologies have fostered the emergence of innovative forms of architectural practice based on collaborative working methods. Architectural education is not left out of these changes. A new kind of professional is needed to act professionally in these new working environments. At present, the architect has to be able to collaborate in multidisciplinary teams and to achieve an instrumental and social mastery of digital technologies. In this context, the challenge of schools of architecture nowadays is to review the traditional pedagogic models to develop methods of learning that enable them to adapt to the current professional situation. Thus, the Design Studio (considered as the core of education in architecture) needs a reconceptualization to change the way architects should learn. The implementation of different digital technologies -like BIM, parametric design and digital fabrication- in the Design Studio can help to transform it into a new integrated and experimental learning space. Consequently, we can see today the Design Studio as a network of places where different types of learners and institutions can participate in the design process, and, simultaneously, collaborate in the creation of the architectural knowledge. This paper reviews the recent adoption of the aforementioned tools in education by describing some successful cases in different universities. It summarizes the benefits of using these tools in training students who gain expertise at digital labs which could be carried out through a network of physical and virtual learning spaces. The paper concludes that the gap between academia and the professional field would be filled by changing the Design Studio to a Digital Design Lab.

Keywords: Architectural design, BIM technology, Design education trends, Digital fabrication, Parametric design.

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Introduction

The Professional Practice of the Architect in Today's Society

In the 1970s and 1980s, the emergence of digital technologies, especially computer-aided design programmes (CAAD: Computer-Aided Architectural Design), revolutionized design methods and introduced new design tools which changed the development processes of the architectural project and its results. According to Muñoz, this technological revolution has produced significant changes in the field of architecture such as the digitization of documentation, the use of computer-aided design techniques and the new access to information. The digitization of documents has enabled a major improvement in speed and efficiency at the moment of generating, modifying and storing the projects' information (especially graphic material). The computer-aided design techniques have become a new tool for conceiving and drawing architecture and, the access to information through the consultation of databases and Internet has provided the architect with a broad view of contemporary culture and a better understanding of the Architecture, Engineering and Construction (AEC) sector[1]. In addition, these three changes have acted as a catalyst in the processes of technical and design innovation, transforming the way architects conceive and design the architecture.

Nowadays, architects use a wide variety of techniques and instruments whose choice depends on the features of the design object to be represented as well as the objectives of the graphical representation. Albert Gil and Areti Markpoulou, however, claim that today the most appropriate instruments to develop an architectural project are Building Information Modelling (BIM), parametric design and digital fabrication[2]. Nevertheless, despite the potential that these digital technologies can offer us today, Coloma also argues that their implementation in some countries, such as Spain, is slow because professional experts are unaware of their real scope and distrust their results[3].

BIM is a technology that has been developing for more than twenty years in the United States and Europe. However, BIM implementation has been slow compared to other programmes[4]. The concepts and working methods that today are included under the term BIM have their origins in the '70s when Eastman described the concept of *building description system* in the article '*The Use of*

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[1] Alfonso Muñoz Cosme, *El Proyecto de arquitectura. Concepto, proceso y representación* (Barcelona: Editorial Reverté S.A., 2008), 57-58.

[2] For more information on this topic, see the conference '*Dimecres tecnològics: Aproximació al disseny arquitectónic amb BIM*' (Technological Wednesday: An Approach to Architectural Design with BIM) organized by the COAC (Architects' Association of Catalonia) on January 28 (2015) and the conference 'UOCMeet: Smart Building' organized by the Open University of Catalonia (UOC) and Construmat on February 7 (2015) on websites: https://www.youtube.com/watch?v=2hy9F_zvExY, and http://social.alumni.uoc.edu/uocmeet/es/2015/02/07/uocmeet-smart-building/. Albert Gil is an architect in the Batlle i Roig studio (Spain) and Areti Markpoulou is the academic director of the Institute for Advanced Architecture of Catalonia-IaaC (Spain).

[3] Eloi Coloma Picó, *Tecnologia BIM per al disseny arquitectònic* (Doctoral Thesis. Barcelona: Universitat Politècnica de Catalunya, 2012), 20.

[4] Ibid., 76.

Computers instead of Drawings in Building Design'[5] and Mitchell also mentioned the idea of *building descriptions based on computers* in '*Computer-Aided Architectural Design*'[6]. Nevertheless, despite its early development, its integration in architectural studios and engineering consultancies has been progressive due to the influence of other traditional design tools and methods.

At present, this trend has changed as a result of several factors such as the increase of the buildings' complexity, the clients' pressure to quickly develop projects and efficiently manage production costs and the need to transfer information to other disciplines. Architectural studios and engineering consultancies, with the purpose of providing better service and adapting to the professional requirements, have gradually adopted the BIM technology as a working method. Several professional groups have started to design various strategic plans to achieve the international implementation of BIM in the AEC sector. For example, in the United States under the leadership of the US General Services Administration (integrated into the US National Institute of Building Science) and the BuildingSMART Alliance[7], different agreements have been established in order to promote the widespread use of BIM. Meanwhile, in the United Kingdom, the Government Construction Client Board has developed a plan to achieve a certain level of integration of BIM in the AEC sector in the coming years[8]. In the case of Spain, the implementation of BIM technology is also making progress although slowly because the institutional support has so far been lower. Recently in the professional field, however, numerous initiatives have emerged to promote its implementation in architectural studios and engineering consultancies[9].

Ren and Zhang also comment that BIM software has become increasingly important in the international AEC industry because architects can take measures to improve efficiency design and construction work, to save costs and to shorten the construction timeframe[10]. This is due to the ability of the BIM technology to facilitate communication and collaboration between different actors (architects, engineers, contractors, builders and customers) who are involved throughout the entire life cycle of a project. These actors, through a

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[5] Charles M. Eastman, "The Use of Computers instead of Drawings in Building Design", *AIA Journal* 63, no. 3 (1975): 46-50.

[6] William J. Mitchell, *Computer-Aided Architectural Design* (New York: Van Nostrand Reinhold Company, 1978).

[7] For more information on these agreements, see: http://www.buildingsmart.org/

[8] Department of Business, Innovation and Skills, *Building Information Modelling (BIM) Working Party*, a report for the Government Construction Client Group, March 2011, retrieved from http://bit.ly/2h2o9Ei.

[9] Recently, Spanish professional institutions have created various courses and have organized several conferences on the future potential of BIM in the profession. In 2016, the Consejo Superior de Colegios de Arquitectos de España (Council of Architects' Association of Spain) has published a survey on the implementation of the BIM system in Spanish professional studios. This survey can be downloaded from the web: http://bit.ly/2zOlrxL. The COAC (Architects' Association of Catalonia) has also created a working group which purpose is to bring the BIM technology to architects and to facilitate its adoption. To learn more about the group and its activities see: https://www.arquitectes.cat/es/grupo-de-trabajo-de-bim.

[10] Shuo Ren and Weihan Zhang. "Application of BIM Software in Construction Design Education", *World Transactions on Engineering and Technology Education* 12, no. 3 (2014), 432.

process of collective information management, build a virtual model which can be continuously updated and used as a database for consultation during and after each job. Thus, the BIM technology has not only revolutionized the process of drawing production[11] but also the access to information stored in a centralized model. It has created new workflows[12] which are changing the way of designing projects and the functions of the architect.

Parallel to the BIM technology, architectural studios and engineering consultancies have also been implementing parametric design tools in order to develop their projects[13]. According to Stavric and Marina, digital modelling and visualization of architectural buildings has become the benchmark in the work of architects[14]. The original 2-D programmes used for drawing architectural designs has now turned into intelligent 3-D software packages based on parametric modelling. This new parametrically based approach in architectural design enables the architect to search for a completely new level in the form generating process. Parametric design, beyond its usefulness to control complex structures, allows architects to explore new ways of formal expression through the fusion of mathematics and geometry. For instance, currently architects can use a wide variety of programming resources to create small applications in order to generate forms from script language (routines) and, finally, to design a façade or an entire building. In this case, the use of algorithms and object-based programming allows architects to obtain an infinite variety of design forms that can be reviewed and manipulated without creating them manually. In addition, these tools are also used to study, from the earliest stages of the design process, the structural, morphological and energy performance of buildings.

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[11] An object, designed with BIM, contained in a single virtual model all the needed information to develop the project. As a consequence, architects can work the object simultaneously from different views (plan, section, elevation and 3D model). Besides, they can also analyze the object not only in geometrical terms but also in descriptive and parametric terms. On the contrary, when architects use traditional tools of representation, they produce synthetic representations of the object. These representations describe different parts of the object (elevation, floor plans and sections) but are not connected to each other. This work system has many limitations because if architects decide to make any modifications, they have to redraw any changes in all representations. Moreover, these restrictions also affect other experts involved in the design and construction process since the information cannot be managed collectively. It is usually used in a fragmented and incomplete way in different parts of the process. Thus, coordination and cooperation among experts is less dynamic.

[12] Architectural studios and engineering consultancies have adopted a more open and flexible work structure based on Integrated Practice. This BIM principles-based work methodology consists of a holistic approach to building in which all project stakeholders and participants can work in highly collaborative relationships, either as fully integrated firms or in multiform partnerships, using a 3D virtual model with all the necessary information concentrated in connected databases.

[13] For more information on the integration of parametric design programmes and digital fabrication in architectural studios and engineering consultancies see, among other authors, Stephen Kieran and James Timberlake, *Refabricating Architecture. How Manufacturing Methodologies are poised to Transform Building Construction* (New York: McGraw-Hill, 2004); Hanif Kara and Andreas Georgoulias, ed. *Interdisciplinary Design. New Lessons from Architecture and Engineering* (New York: ACTAR Publishers, 2012).

[14] Milena Stavric and Ognen Marina, "Parametric Modeling for Advanced Architecture", *International Journal of Applied Mathematics and Informatics* 5, no. 1 (2011): 9.

Another current design approach for architectural studios and engineering consultancies is to investigate computer numeric controlled (CNC) manufacturing methods such as CNC-bending, wire-cutting, laser-cutting or CNC-milling and to implement their inherent geometric properties as input design parameter in projects. Architects use these digital fabrication tools to explore manufacturing and material properties and, the way these can be linked to geometry and design[15]. Nowadays, digital fabrication machines are considered by design experts as devices that automatically translates a digital object into a material realization. Consequently, professionals can create and produce building skins that result not only in new expressive material qualities but also in new geometric shapes which respond to environmental, structural and functional conditions.

Changes in Architectural Education

In this context, architectural education is not left out of these changes[16]. In the professional field, a new kind of expert is needed. Architects must acquire different skills and knowledge in order to act professionally in these new working environments. At present, the new professional has to be able to achieve a high instrumental and social mastery of new digital technologies, to integrate other disciplines in the design process and to combine different skills related to the design, research, management and consultancy of architectural projects. Furthermore, this professional must possess the necessary skills (generic and specific) to work in multidisciplinary teams which can be geographically distributed around the world[17] and to use a wide variety of digital tools to develop new design and construction procedures.

However, despite the changes that are occurring in the profession, the training of architects in schools of architecture continues to focus on the individual work of the architect (as a designer and a privileged professional) and on traditional educational models that have grown more and more distant from the professional demands[18]. Even so, it is very likely that future graduates

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[15] Sigrid Brell-Çokcan, Martin Reis, Heins Schmiedhofer and Johannes Braumann, "Digital Design to Digital Production: Flank Milling with a 7-Axis Robot and Parametric Design", in *Proceedings of the 27th Conference on Education and Research in Computer Aided Design in Europe* (Istanbul, Turkey, 2009), 323-324.

[16] On this question, see the following authors who refer to the new situation of change in the schools of architecture: Michael Chadwick, ed., *Back to School: Architectural Education- The Information and The Argument* (The United Kingdom: Willey-Academy, 2004); CSCAE, ed., *Arquitectos Estrategias de formación* (Madrid: Artes Gráficas Palermo S.L., 2007); Daisy Froud and Harriet Harriss, ed., *Radical Pedagogies. Architectural Education and the British Tradition* (The United Kingdom: RIBA Publishing, 2015); Ashraf M. Salama, *Spatial Design Education. New Directions for Pedagogy in Architecture and Beyond* (The United Kingdom: Ashgate Publishing Limited, 2015).

[17] Burcin Becerik-Gerber, David J. Gerber and Ku Kihong, "The Pace of Technological Innovation in Architecture, Engineering, and Construction Education: Integrating Recent Trends into the Curricula", *Journal of Information Technology in Construction* (ITcon) 16, (2011), 412.

[18] On this topic, see: David Nicol and Simon Pilling, ed, *Changing Architectural Education. Towards a New Professionalism* (London: Taylor & Francis Group, 2000); CSCAE, ed., *Arquitectos Estrategias de formación* (Madrid: Artes Gráficas Palermo S.L., 2007). More information can be found in the proceedings of the following international conferences:

have to collaborate with other professionals in architectural studios or engineering consultancies. These professionals will probably use digital technologies (such as BIM, parametric design and digital fabrication) to work and communicate with each other from the early stages of the project. If so, what sense does it make to force students to receive a traditional education which does not meet the current professional demands?

In view of this, schools of architecture have been forced to revise their programmes in order to develop teaching methods that enable them to adapt to the current professional situation. As Ambrose states, academia must completely revisit the current curricula and imagine a system that acknowledges the obsolescence of the how and what is taught in today's schools of architecture[19]. Because of this, it is the duty of architectural schools to properly adapt their curricula to turn their students into capable professionals.

In the last decades some authors, such as Oxman[20] and Deamer & Bernstein[21], have also addressed the need to integrate digital design in architectural education because there is a call for educating a new generation of digital design specialists. Nonetheless, the demand to accommodate this professional change in academia presents a challenge: to explore and develop new pedagogical methods which can contribute to reformulate the learning objectives. In this sense, the BIM technology, parametric design and digital fabrication represent a shift in thinking with regard to the architectural education. These digital tools have the potential to fundamentally transform the way in which architectural education engages issues of design and suggest opportunities to question the rules of the traditional education.

Thus, when these digital tools are implemented in the teaching of architecture, the result is that the traditional model of the Design Studio[22]

"*Change, Architecture, Education and Practice"* organized by the Association of Collegiate Schools of Architecture (2012) and "*(un)common currency"* organized by the Nottingham Trent University and the Association of Architectural Educators (2013).

[19] Michael A. Ambrose, "BIM and Integrated Practice as Provocateurs of Design Education", in *Proceedings of the 12th International Conference on Computer Aided Architectural Design Research in Asia* (Nanjing, China, April 19-21, 2007), 284.

[20] Rivka Oxman, "Digital Architecture as a Challenge for Design Pedagogy: Theory, Knowledge, Models and Medium", Design Studies 29, no. 2 (2008), 99-120.

[21] Peggy Deamer and Phillip G. Bernstein, ed., *BIM in Academia* (New Haven: Yale School of Architecture, 2011).

[22] In academia, the term *Design Studio* is used to designate the space and place (in a non-physical sense) where professional practice is simulated in order to instil the necessary professional skills and competences in students. Whereas the term *studio* has a physical component that determines a particular space in which the activity of design occurs, the term *design* represents the action of teaching architecture. In this document, the term *Design Studio* is also used to refer to a generic model whose purely methodological characteristics remain unchanged regardless of its specific implementation in a given place and time. The traditional model of the Design Studio (mentioned here) is characterized as a constructive learning model of reality where a situation that would occur during the practice of the architect is reproduced in an academic context. Typically, in a Design Studio, the learning processes happen when students develop a project in stages: identification of the problem, information gathering, development of a design solution, discussion of the results with tutors and peers, intermediate reflections and, finally, the presentation of a project for critical assessment by a panel. During the course of these stages students get a comprehensive view of the complexity of a project and acquire some expertise. Nevertheless, this traditional model has certain limitations which directly affect the current

(considered as the paradigm in the training of architects) experiences a process of transformation[23]. Today, the Design Studio is evolving into new types of physical and virtual learning spaces that are characterized for being interdisciplinary, transdisciplinary, experimental and next to the professional field. Moreover, in these integrative and research learning spaces, students can collaborate with different institutions (universities, public entities and companies) and people (students, specialists from different disciplines and citizens) in the various stages of the design and construction process of a project using digital technologies (BIM systems, parametric design programmes and digital fabrication machines) as a means of communication and work.

The Reconceptualization of the Design Studio: New Learning Spaces

Digital Technologies as Factors of Transformation in the Design Studio

Previously, we have seen that the incorporation of parametric design, digital fabrication and the BIM technology in professional practice has led to changes in the design process of the projects, the working methods and, by implication, the role of the architect. In the first case, parametric design and digital fabrication programmes have helped to produce a wide variety of architectural solutions (physical and virtual) that allow exhaustive research of all design and technical aspects of an object. In the second case, the BIM technology has become an advanced media that has changed how teams work and communicate. Through a model that contains all the information of the building, different experts can remotely cooperate, exchange material, add accurate data and make drawings more precisely.

In this context, the current challenge of schools of architecture is to train professionals with a mastery of new digital technologies, communication skills and ability to research. For this reason, the use of new digital technologies, such as BIM, parametric design and digital fabrication, in academia (especially in the Design Studio) is growing. Gradually, educators are realizing that most educational programmes are designed to place greater emphasis on traditional teaching representational methods and less in new digital technologies. Thus, most graduates do not have enough knowledge and skills to act competently in the current professional context. In this regard, Ambrose and Fry of the University of Maryland (United States) recognize that the Design Studio should focus on new ways of teaching and addressing emergent digital design methods and processes that critically engage and leverage their immediate effects and

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training of students as professionals and which, with the implementation of the digital tools discussed in this text, academics seek to overcome. Among the most prominent limitations, we can cite: the learning activities do not take place in the real professional environment, the design process is developed mostly in an individual way, students are subjected to isolation (in the physical sense but also in the formative sense), and design is a close and linear process of reception (information), interpretation and reaction (development of a proposal). This creates a false sense of professional reality that can only be solved if learning is conceived as an open and participatory process.

[23] Ashraf M. Salama and Nicholas Wilkinson, ed., *Design Studio Pedagogy: Horizons for the Future* (The United Kingdom: The Urban International Press, 2007).

possibilities in architectural production[24]. Meanwhile, María Amparo Casares of the University of Coruña (Spain) considers that teaching new means of digital representation such as BIM or parametric design in the Design Studio should be enhanced in order to respond to current professional demands. Viera Joklova of the University of Bratislava (Slovenia) also thinks that students should get from their training in the Design Studio, skills related to a proficient use of information and communication technology (ICT) and digital technologies in architectural and urban design[25].

Some schools, with the challenge of training skilled architects, have integrated these technologies into their curricula replacing their existing drawing courses[26]. However, as Cheng of the University of Minnesota (United States) comments, some schools adopted digital representation courses by eliminating analog drawing courses and others adapted existing representation courses, making them predominantly digital. The critical unanswered question is: did the studio and representation course truly transform or was new instructional content simply squeezed in?[27] The same author proposes as a solution the integration of new digital technologies in the design process of projects to convert the Design Studio in a space where students can research the latent potentialities of these tools and their practical application in the professional field. In relation to this, Cheng also explains that as a pedagogical and curricular strategy, teaching digital tools by absorbing them into the Design Studio is not highly effective, but will work if the tools are primarily linked with design projects and integrated into the design process. If the tool does not fit within these strictly defined criteria, the strategy begins to fail. This failure is partly due to the loss of overlap between design time and software-learning

[24] Michael A. Ambrose and Kristen M. Fry, "Re:Thinking BIM in the Design Studio. Beyond Tools … Approaching Ways of Thinking", in *Proceedings of the 6th International Conference of the Arab Society for Computer Aided Architectural Design* (Manama, Kingdom of Bahrain, 2012), 79.

[25] These opinions are fragments of the questionnaire on the current teaching in the Design Studio which was conducted in 2014 during the development of our doctoral thesis [in fieri]: *The Transformation of the Design Studio in New Learning Spaces. A Study on the Process of Integration between Education and Professional Practice*. A questionnaire on how architecture is currently taught in the Design Studio was carried out in order to compare the generic approach of the thesis with concrete examples. Initially a list of architectural schools from different countries and recognized for their academic work was made in order to limit the scope of research in specific cases. 100 questionnaires were sent and 26 replies were received from countries such as Spain, USA, Japan, Holland, Italy, Colombia, Japan, Slovakia, Denmark, Puerto Rico and Germany. With these replies, the current situation of the architectural education was studied from a very general perspective. The topics studied were: what type of projects are developed in the Design Studios, the methodology adopted, the features of the physical and virtual environments where the learning activities take place, the role of the teacher and the student, the profile of the architect adopted as a reference, what kind of presentation systems are used and what changes should be made to respond to current professional needs.

[26] For an analysis of the implementation of digital technologies in the curricula of schools of architecture, see: Luís Agustín Hernández, Angélica Fernández-Morales and Miguel Sancho Mir, "Estrategias docentes para el proceso de trabajo BIM", in *Actas del 16 Congreso Internacional de Expresión Gráfica Arquitectónica* (Alcalá de Henares, Spain, 2016).

[27] Renée Cheng, "Facing the Fact of BIM: Architectural Curricula Past, Present, and Future", in *BIM in Academia* (ed.) P. Deamer and P.G. Bernstein (New Haven: Yale School of Architecture, 2011), 17.

time[28]. Thus, the teaching of digital technologies in the Design Studio would not be based solely on their management as drawing tools but also in their social use related to teamwork, customer relations and collective construction of architectural knowledge.

The Design Studio as an Integrative Learning Space Using BIM

The ability of the BIM technology to facilitate communication between different professionals is an important aspect to consider in the education of future architects. Educators emphasize the need to implement in academia a new interdisciplinary and transdisciplinary teaching model in which students from different courses or disciplines can work together on a project and learn from each other[29]. The use of the BIM technology as a communication tool would be valuable to promote the knowledge of architects in other disciplinary fields and to improve their ability to participate in collaborative and integrated environments. In relation to this, for example, Berwald of the University of Montana (United States) recognizes that there is a great opportunity in the classroom to mirror the growing degree of collaboration that BIM affords us[30]. Architecture, Engineering and Construction Management students might all benefit from working as a team in an educational environment and using the technology that allows them to work together on the same project.

Based on this idea, some schools of architecture have integrated the BIM technology as a method of design in the Design Studio. In this way, students can acquire skills related to the representation of architectural ideas and the production of images (software skills) but, at the same time, other skills related to communication, collective information management and teamwork (lateral skills). The main objective of these schools is to transform the Design Studio in an integrative and cross learning space at different scales where students are endowed with the necessary knowledge (instrumental, creative, social and technical) for the design and construction of diverse projects (from the development of a constructive detail to urban planning of a city).

For instance, the *Columbia Building Intelligence Project* (C-BIP)[31] was created at the Columbia University (United States) in order to establish a new Design Studio that would respond to the growing complexity of design problems and the emergence of new forms of professional collaboration[32]. The

[28] Ibid.

[29] Sawsan Saridar Masri, "Improving Architectural Pedagogy toward Better Archistructural Design Values", *Athens Journal of Architecture* 3, no. 2 (2017), 120.

[30] Sarah Berwald, "From CAD to BIM: the Experience of Architectural Education with Building Information Modeling", in *Proceedings of the ASCE Conference* (Denver, United States, 2008), 72.

[31] Scott Marble, David Benjamin and Laura Kurgan, "Columbia Building Intelligence Project (C-BIP) and the Integrated Design Studio", in *BIM in Academia* (ed.) P. Deamer and P.G. Bernstein (New Haven: Yale School of Architecture, 2011), 68-85.

[32] This paper reviews some study cases as a vehicle to test their theoretical discourse at a pragmatic level. The following three examples have been selected, among others, to show briefly how the Design Studio is turning into an integrated learning space thanks to the implementation of the BIM technology in teaching and learning processes. The authors are aware that there are other cases which are not discusses here, but we consider that these three projects (for their academic relevance) can help to establish a holistic view on the integration of BIM technology in the Design Studio. The *C-BIP project* of the Columbia

C-BIP project, through an organizational structure of Integrated Design Studios (IDS), aimed at promoting the exchange of information between students of different Design Studios through a database and at fostering teamwork using BIM and other simulation programmes as work and communication tools.

In the *C-BIP* project, unlike the traditional model of the Design Studio in which students regularly produce designs individually, teachers created a collaborative work environment where design results were shared with other students from other studios. Students had to create multiple parametric building elements taking into account a number of environmental indicators (mitigation of energy in buildings, water collection, heat reduction and solar energy capture). Once these elements were developed, the information was stored in an open digital library to be reused later. After this first stage, students of each Design Studio formed groups to design different *building strategies*, which had to be applied to six existing buildings in New York City, combining the multiple elements available in the database. Students had to choose one building to integrate the initial design of their elements into the façades, roofs or courtyards. The designs were driven not only by energy metrics but also by the challenge of creating significant architectural and urban interventions.

A premise of the project was that only the authors of each element can make adjustments to their designs. If a team needed to modify an element to fit into its design proposal, they had to ask the author to make the appropriate changes. Thus, students continuously received feedback and, therefore, teams had the possibility to view and download new building elements that could be used to carry out their design proposals. This project represented a unique experience for the students of these Design Studios because learners with different levels of expertise were integrated in a single working environment. These students also learned to use the BIM technology as a means to cooperate together and to share responsibilities during the development of a project. Besides, they had the opportunity to work individually and in groups simultaneously in two projects. This is a fact that does not happen in a traditional Design Studio where individual work is encouraged and collective work is reduced to certain situations such as informal group reviews and formal presentations.

Another case is the vertical Design Studio[33], known as *Collaborative BIM Studio*, organized by the University of Pennsylvania (United States). The working groups were formed by students of the third and the fifth year. They were studying architecture, landscaping, construction, structural engineering,

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University (United States) has been selected because it is a model of the Design Studio that explores new forms of professional collaboration through an organizational structure of the integrated design studios using BIM and performance simulations. The vertical Design Studio of the University of Pennsylvania (United States) is characterized as an interdisciplinary and participatory learning space where students from different academic levels and disciplines develop together different stages of a project (budget, design, planning and marketing) from a basic BIM model. Finally, the Design Studio of the University of Maryland (United States) is also an example of a learning space related to the professional practice where students, in collaboration with architects, engineers and consultants, design a new proposal by introducing specific changes in a BIM model.

[33]Ute Poerschke, Robert J. Holland, John I. Messner and Madis Pihlak, "BIM Collaboration Across Six Disciplines", in *Proceedings of the International Conference on Computing in Civil and Building Engineering* (Nottingham, the United Kingdom, 2010), 575-580.

mechanical engineering and lighting engineering. Their task was to review the design of a prototype of an elementary school using the BIM technology for data collection and coordination, energy analysis, design development and project presentation. Students had a preliminary design of the building to accelerate the early stages of design and to focus more on other aspects such as cost estimation, troubleshooting or planning work. The learning tasks were to critically review the original BIM model, to develop a new design proposal (with emphasis on the sustainability of the building), to carry out an analysis of the costs and to realize a planning programme. Finally, teams (made up of students from different disciplines) had to make several public presentations in order to show their progress.

According to Poerschke, Holland, Messner and Pihlak[34], the Design Studio was a positive experience as it helped students to understand the different technical, aesthetic and social aspects of the design process of the project, to acquire the right skills to collaborate with experts from other professional fields and to obtain the necessary knowledge to use correctly digital technologies (as an instrument of representation and social interaction). In a survey conducted later, the same authors also claimed that students felt that the design process was carried out slowly due to the large number and variety of inputs provided by each discipline. Furthermore, although the BIM platform allowed them to participate in the work of others, most students found that the interoperability of the software and the lack of familiarity with some programmes were an added difficulty. The students expressed on several occasions that the best solution would have been to attend some lectures on BIM modelling before starting the Design Studio in order to gain more experience and confidence with the programme.

At the University of Maryland (United States) the BIM technology was also used to transform the Design Studio into a participatory learning space where the professional field is integrated[35]. Unlike the previous project, students collaborated with architects, engineers and consultants who developed the original project. During the first weeks, the students participated in different sessions to analyze the original BIM model. Students, with the help of these experts, came to understand better how the different systems that make up the digital model (structure, facilities and construction elements) are integrated and how the technical and creative contributions of every specialist complement each other.

In the second phase, students changed one of the BIM model systems replacing the original steel structure of the building with another structure of prefabricated concrete. For several weeks, students -divided into two groups- worked hand in hand with structural engineering consultants and architects of the original project to redesign the structure of the building taking into account issues like the new dimensions, the building restrictions, the logistics of the new project or the changes of the interior spaces and the façade. This exercise was designed in order to make students understand that the design work is

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[34] Ibid., 577-578.

[35] Michael Ambrose and Kristen M. Fry, "Re:Thinking BIM in the Design Studio. Beyond Tools …Approaching Ways of Thinking", in *Proceedings of the 6th International Conference of the Arab Society for Computer Aided Architectural Design*, (Manama, Kingdom of Bahrain, 2012), 71-80.

carried out iteratively between different specialists involved in an architectural project and to make them conceive the BIM model as a whole in which they can constantly add data allowing the project to evolve consistently.

In the third phase of the Design Studio, students work individually in the design of a new façade using a curtain wall system. Teachers assigned a programme with specific requirements (environmental, technical and performance) to each student. To test the feasibility of the constructive system, students conducted several design tests building physical prototypes and performing digital simulations in the BIM model. According to Ambrose and Fry, the ability to develop physical models and, at the same time, to perform simulations using the BIM technology allowed students to explore the iterative nature of the architectural design[36]. The idea of incorporating small changes in the project served to teach students that, unlike the conventional design processes in which architects work on an initial idea, the BIM technology allows to develop and explore infinite design solutions. Moreover, with each advance, students had the opportunity to re-evaluate the acquired knowledge and to reiterate the work done previously through the permanent exploration of the original model and its new versions.

In all three cases, with the implementation of the BIM technology in the learning tasks, the Design Studio was transformed into an integrative learning space at different scales (between students, subjects, disciplines and professionals). Its integration entails certain advantages and drawbacks. For example, some technical advantages are: students have to work the design object in a three-dimensional way, to apply the creative and constructive elements since the beginning of the project and to solve all problems by developing the best possible design solutions in an iteratively way, questioning at every moment every decision made. Otherwise, there are also social advantages such as the fact that the BIM technology allows students to communicate effectively with each other and other learners (from the academic and professional field), to work in a team (in a physical and virtual environment) and to digitally visualize the final results. Moreover, the usual disadvantages that students face and that add more difficulty to the learning process are: the lack of experience in managing the programmes and the deficiency of advanced knowledge of the construction and the management project. Nevertheless, these three cases are an example of how the implementation of the BIM technology in teaching architecture can be carried out not only for instrumental purposes but also for social ones. Beyond being only a set of representational tools, BIM can be used to teach students interpersonal and proactive skills.

The Design Studio as an Experimental Learning Space Using Parametric Design and Digital Fabrication

Schools of architecture are also integrating the parametric design and digital fabrication tools in the Design Studio to create learning spaces that encourage the creative and experimental ability of students regarding the design and production of digital and physical models. Sass of the Massachusetts Institute of Technology (United States) and Oxman of the Israel Institute of

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[36] Ibid., 75.

Technology (Israel) recognize that these tools afford opportunities not only to create complex shapes, but also to serve as intermediary between the design and construction phase[37]. Thus, unlike the traditional methods that are commonly used in the Design Studio, the use of these appliances and software extends creative design beyond the early stages of design and supports the continuity of design through its various stages.

The implementation of these tools in the Design Studio also means an opportunity for students to understand the impact each step and variable of the process has on the design and, also, to follow the influence of their decisions on the project. The result is that students begin to think about design problems in different ways. They have to try new methods of design thinking and exploration in order to solve a design problem using applications that focus on the parametric dependencies of spatial perception, environmental conditions, structural systems, fabrication and form finding. In this way, concepts like *design questioning* and *design reflection* become the centre of the design process because students develop the project by using sets of parametric variables and series of relations which help to question, create and define the form and function of the resulting designs.

For instance, the *DAw* project[38] was created at the International University of Catalonia (Catalonia-Spain) to investigate the impact of the parametric design tools and the digital fabrication equipment in the practice of architecture[39]. Teachers organized a Design Studio around the idea of *emergency*. Students used the parametric design programme Top Solid to design different solutions from an interactive model that could be adjusted to respond to different emergency situations. Simultaneously to the work of the development of diverse digital models, students produced several prototypes at different scales using CNC machines in order to study in situ the results.

[37] Larry Sass and Rivka Oxman, "Materializing Design: the Implications of Rapid Prototyping in Digital Design", *Design Studies* 27, no. 3 (2006), 326.

[38] Marta Malé-Alemany and José Pedro Sousa, "Hyper [D-M] Process. Emerging Conditions for Digital Design and Manufacturing in Architecture"; in *Proceedings of the 21th eCAADe Conference* Graz, Austria, 2003), 343-346.

[39] The following four examples have been selected, among others, to show briefly how the Design Studio is turning into a space for digital experimentation and research thanks to the implementation of the parametric design and digital fabrication tools in teaching and learning processes. The *DAw project* of the International University of Catalonia (Catalonia, Spain) has been selected because it represents an example of the Design Studio where the parametric design and digital fabrication tools have been integrated in the design process so that students can experiment with different design solutions generated with digital interactive models and physical prototypes. The Design Studio of the Feng Chia University (Taiwan) and the Architectural Association of London (United Kingdom) is also an example of an innovative educational model where students use simulation programmes as a means to investigate how the meteorological phenomena can impact in the design of buildings. The Design Studio of the University of Seville (Spain), known as *Fabbing CC. Fabricación digital comunitaria* (Fabbing CC. Community Digital Fabrication), is characterized by investigating the potential of social innovation of the computer technology and digital fabrication in the development of urban projects. Finally, the *FabLab House* project of the Institute of Advanced Architecture of Catalonia (Catalonia, Spain) and the Massachusetts Institute of Technology (United States) is an example of the Design Studio based on the Experiential Learning. Students, in collaboration with different FabLabs and professional companies, develop a research project related to energy efficiency using CAD-CAM technologies as a work tool.

According to Malé-Alemany and Sousa, the use of these instruments in the Design Studio turned out to be an interesting way to spread among students the knowledge of new ways to develop architectural projects on a conceptual and technological level[40]. In addition, the CAD-CAM technology was useful to improve the design and the fabrication processes. Traditionally a project is developed through a linear sequence of steps. The design and the fabrication are separate stages, each with its own means of representation. To switch from one to another, multiple processes are required. By constantly changing means and techniques, the continuity of the process is interrupted. However, as students could check with the integration of a parametric design programme in the *DAw* project, this discontinuity was solved when they could work from the first to the last phase of the project with a single interface (using a single language) that promoted the flow of information necessary for a truly interactive design process.

In the case of the Feng Chia University (Taiwan) and the Architectural Association of London (United Kingdom), the simulation programmes were integrated into the Design Studio as a means to investigate the impact of parametric tools in the earliest phases of the design process and the influence of meteorological phenomena in the design of sustainable buildings[41]. In the *Weather Unit* workshop, students used various simulation tools such as the Autodesk Maya programme to study the dynamics of weather phenomena in a given urban area and to develop diverse timing diagrams. These diagrams were then aligned to specific material performances and used to create varying atmospheres within the city. Later, they served to create several prototypes of surfaces. For instance, student Billy Choi worked the phenomenon of saltation (the rising of wind when the snow is blown near the ground) using Maya software to simulate the physical forces of the particles and to test them on a building proposal in order to obtain an optimal form. According to Roe and Wu, this process of investigation and experimentation allowed him a direct translation of such particle dynamics into an accurate geometry even if it was not a true physics simulator[42].

With this exercise, the teachers tried to establish a link between the dynamic simulation and the generation of geometric forms during the early design stages of a project and to familiarize students about concepts related to the dynamics, pressures or forces exerted by the natural elements in buildings. In this regard, Roe and Wu explain that the goal of the Design Studio was to play with different parametric design tools. This gave students the freedom to approach the project from different angles. Sometimes students misused these tools but, as a result of this, they gained experience which became part of their background knowledge[43]. Thus, at the end of the Design Studio, the students were able to use any simulation programme during the design process, to understand the design results and their implications and limitations, and to be

[40] Ibid., 346.
[41] Stephen Roe and Chiafang Wu, "Simulation in Architectural Design Education -Report on, an Assessment of, an Integral Approach within the Design Studio", in *AAE International Conference on Architectural Education: (un)common currency* (Nottingham, the United Kingdom, 2013), 278-283.
[42] Ibid., 279.
[43] Ibid., 280.

prepared to participate proactively with other professionals in performing more accurate simulations in later phases of the project.

At the same time, the task of creating prototypes is gradually being introduced in the traditional model of the Design Studio as a learning activity based on the investigation and the resolution of real problems. By combining the parametric design programmes with digital fabrication tools, students can make prototypes at different scales of the digital models generated during the development of the project. They can experiment with several design proposals and verify in situ their morphological and structural performance. The learning activities of these new Design Studios focus on the social potential of the computer and fabrication technologies and on their application in the creation of urban and housing facilities on a scale of 1:1 in order to meet the needs of a client (neighbourhood communities, private companies or public administration).

For instance, in 2011 the FabLab of the University of Seville (Spain) organized the Design Studio, known as *Fabbing CC. Fabricación digital comunitaria* (Fabbing CC. Community Digital Fabrication)[44]. The purpose of this Design Studio was to create a participatory learning environment where new lines of social research linked to the digital fabrication could be developed. The project was divided into three workshops to coordinate all activities and to facilitate the participation of local institutions and neighbourhood associations. In the first workshop, possible lines of intervention in the urban space were discussed and an online platform was created in order to promote collaborative work and to make the process publicly available. In the second workshop, after collecting all the citizens' suggestions, students began to digitally create various proposals (mainly small structures of urban furniture) and, then, to manufacture them on a small scale for their public presentation. After this second workshop, two proposals were chosen for prototyping more accurately (first, in cardboard on a scale of 1:10 and, then, in plywood on a scale of 1:1). Finally, in the last workshop, students and the residents assembled and installed on site all the pieces to build the designs made at the school. During this last phase of manufacturing and assembling, various modifications were made as a result of a continuous process of feedback and learning about the ability of the machinery and the behaviour of materials used.

This project represented a singular educational experience because it was an opportunity for the students to build a project which has been designed in the school and to understand the diverse technical and social aspects of the profession. In addition, students could design a real project combining and experimenting with traditional and new working methods and tools. In this regard, José Pérez de Lama (the director of the FabLab) commented that this

[44] For more information on this Design Studio and others similar carried out by students of the schools of architecture of Seville, see: Manuel Gutiérrez Rueda García, José Pérez de Lama Halcón, Narciso Vázquez Carretero and Percy Durand Nyera, ed., *FabWorks. Diseño y Fabricación Digital para la Arquitectura. Docencia, Investigación y Transferencia* (Sevilla: Universidad de Sevilla, 2011); José Pérez de Lama Halcón, Antonio J. Lara Bocanegra and Narciso J. Vázquez Carretero, ed., *Yes, We are Open! Fabricación digital, tecnologías y cultura libres* (Sevilla: Universidad de Sevilla, 2014) retrieved from http://fablabsevilla.us.es/index.php/ficheros/category/3-publicaciones. The FabLab also has a blog: http://fablabsevilla.us.es/.

kind of Design Studios, where students can experience first-hand the influence of the manufacturing tools on the traditional processes of development a social project, are useful for teaching how students can have greater control over the development and results of the design product and, at the same time, how they can incorporate into the process other people such as citizens or public representatives[45].

In the case of the *FabLab House* project[46], conducted by the Institute for Advanced Architecture of Catalonia (Catalonia-Spain), the Massachusetts Institute of Technology (United States) and the global network of FabLabs, a housing prototype was designed and built on scale of 1:1 with CNC machines for the European Solar Decathlon competition. In this occasion, the work was carried out between universities of different countries and professional companies (Endesa, Schneider Electric, Visoren and Roca, Santa & Cole, Vinçón, Nani Marquina, Hp Spain or Finnforest Merk Factory). The students had the opportunity to get exposure to a different educational experience that allowed them to learn first-hand about how architects work in international and multidisciplinary teams (formed by researchers, Iaac board, FabLab Barcelona, MAA Thesis Project Students, MIT Center for Bits and Atoms, Solar Decathlon Students, Solar Energy Students and Summer Workshop Students) and how a project of this scale is developed using new digital technologies. Additionally, students also could work with new professional design strategies and explore innovative building materials using the resources of the environment to create a microclimate that passively optimized the basic conditions of habitability.

The housing prototype was conceived as a combination of various teaching strategies. The first strategy was to use the CAD-CAM technologies as a working tool to design and build a customized house. The second strategy intended to measure the effectiveness of the materials used in the house through its energy performance but also through its value, price availability, technical complexity, assembly, adaptation and maintenance. Finally, the third strategy was to establish a unitary construction system. To achieve these objectives, several Design Studios were organized around the design and the fabrication process of a prototype. During these Design Studios, important issues such as the manufacture, assembly and transportation of the pieces were treated. Furthermore, students and teachers in collaboration with other professional experts worked together in the development of specific project tasks. For example, teachers organized several work sessions where students and professionals discussed the construction and the transport of the pieces, the calculation of the structure, the design of an outer skin and the planning of the interior spaces. Throughout this process, students built several small-scale prototypes of the house in order to check their viability. Finally, the structure of

[45] This commentary is part of an interview conducted in 2015 during the development of our above-mentioned doctoral thesis. Some well-known teachers and researchers were interviewed in order to know their opinion on the current academic situation and to know what changes they have introduced in their Design Studios and what results they have obtained.

[46] For more information about this Design Studio and the process of design, fabrication and construction of the prototype, see: www.fablabhouse.com/blog/ and http://www.fablab house.com/en/.

the prototype was made with CNC machines in Germany and the rest (interior spaces, outer skin and other construction elements) in the FabLab of Barcelona.

In these four cases, the implementation of the parametric design and digital fabrication tools in the learning processes has turned the Design Studio into a digital research space. These tools have changed the traditional process of representation of a project into an instrument of design and experimentation where students can incorporate their intentions as designers in the most embryonic stages of the project and, then, materialize them. Students no longer have to think in finished forms but in the generation of flexible structures that allow the dynamic addition of different data at any stage of the design process. Consequently, thinking and creating with parametric design and digital fabrication tools requires a novel and deeper understanding of the overall design goal and its anticipated outcome. This differs from traditional design that deals with one problem at a time. Students can deal with different project problems at the same time because each different design action plays an equally important role. It allows for the study into the causes of problems and their relationships to other design elements directly. This aspect is important for students who can learn by doing and exploring the different design options. At the same time, the digital fabrication tools facilitate the construction of the design proposals at different scales which allow the inclusion of other people (outside the academic field) in the process. As a result of this, the learning of students is enriched by the diversity of contributions made by these specialists and non-professionals. Thus, schools of architecture have established a new type of Design Studio with a different pedagogical approach. Whereas the traditional model of the Design Studio is based on a teaching transmission between teacher and student, this new model focuses on a constructive, experimental and participatory type of digital learning in the studio-lab.

Conclusions: Future Directions of Architectural Education

The Design Studio as a Research, Interdisciplinary and Interconnected Lab

When we examine in detail how the BIM technology, parametric design and digital fabrication is changing the way of teaching at the schools of architecture, we can see that there are some trends that stand out. Thus, we can speculate on the future development of the Design Studio and propose some possible lines of evolution[47].

In the coming years, the current educational model of the Design Studio could be replaced by a new one based on three basic concepts: interconnectedness, interdisciplinarity and research. In this new model, digital technologies would play an important role in the design and the organization of the teaching and learning processes. The digital technologies would act as a transformative element facilitating the tools and the environments where new

[47] In the conclusions, we only propose several generic guidelines on how schools of architecture could continue with the process of transforming the Design Studio due to the general approach of this paper. We consider that the practical application of these guidelines will depend on the context in which schools, programmes, design studios, group of students and pedagogical objectives are integrated and, therefore, neither method nor specific exercises are proposed.

educational practices will be developed. In addition, the teaching and learning of architecture will turn into a participatory process (local and global) that will integrate actors from academia (public and private universities and institutions), the professional practice (companies, public administration, architectural studios and architects' associations) and the social field (neighbourhood associations and users).

The traditional Design Studio could change into a Digital Design Lab. This change would take place because the teaching of architecture would be conceived as research work which would be developed through various experiences and not necessarily limited to the individual realization of a project (as happens now in the schools). This laboratory would have an experimental character. Students would test different design solutions through an exploratory process and, subsequently, they could apply their knowledge in different contexts. The students' learning would focus on the process of performing these solutions, beyond the systematic persecution of predefined results. The BIM, parametric design and digital fabrication tools might also provide a different orientation to the design exploration and the creativity process. Instead of a conventional problem (including context and explicit functional programme) students could use parametric variables as a starting point for design exploration. No programme or specific site would be necessary at the inception of the design since the educational process would not depend on project-oriented learning as in the traditional Design Studio.

The training of students would be carried out through a network of collaborative learning spaces (physical and virtual) dedicated to experimentation and co-creation that would cover various fields such as the technological, artistic and scientific ones. These learning spaces would also stand out for their multidisciplinary approach and their openness (inspired by the principles of open source, free culture and open knowledge exchange). Students would have the necessary technological resources and means to investigate about issues related to the design and construction of architectural, urban and engineering projects. In addition, the learning in these new educational environments would focus on real problems and specific challenges that would involve different professional and academic partners.

In this kind of digital labs, students would adopt the role of entrepreneurs because they would have enough freedom to choose those projects which they wish to develop and investigate. Consequently, students would play an active role in their own learning and the one of their peers from the synergies that would be established remotely and physically during the development of the learning activities. Meanwhile, teachers would assume the task of guiding and accompanying students throughout the entire design and fabrication processes as partners. They would act as a mentor and colleague. Professional companies and architectural studios would also play an important role in the training of students by offering professional advice, sponsoring research projects and providing the necessary resources for the construction and marketing of the proposals.

The boundaries between academia and the professional field would be diluted. The learning activities would be designed to establish multiple synergies with the professional field. Thus, students could learn first-hand about how the practice of the profession is carried out outside schools and acquire the right professional competences. To accomplish this, academic institutions, companies of the AEC sector, architectural studios and engineering consultancies would create associations. The goal of these associations would be to share human and material resources. The pedagogical model of this new Digital Design Lab would therefore become a corporate model where all parties would work and collaborate together to provide students with a tailor-made training that covered specific professional needs.

As a consequence, the centralized traditional model of the Design Studio would lead to a new decentralized model. The teaching and learning of architecture would be carried out in person in the labs at the schools but also remotely in collaboration with other academic and professional institutions dispersed geographically around the world. The number and type of participants might be changing depending on the project that is performed. Finally, this new Digital Design Lab would be characterized as a learning space open to the contributions and the innovations from other professional fields. The learning activities would create opportunities for interaction and connection with other departments of the same school and other institutions. Thus, students could relate to other learners with a different professional profile, discover new ways of understanding architecture, implement projects that deviate from the usual commissions and gain a broader view of the professional practice.

Implementing a Case Study

Taking into account the current changes in teaching, we decided to design a generic Digital Design Lab for architectural studies at the University of Girona (Catalonia-Spain). At present, this project is in its initial stages so it is open to future contributions and modifications derived from its implementation[48]. We are also aware that this will represent a change in the way of teaching of the school focused on a traditional system. However, we hope that its gradual integration into the curriculum will improve the current training of students as they will be able to use digital technologies in order to establish a direct link with the professional practice and to carry out more collaborative and research projects.

The goal of the project *iLab* is to create a virtual platform to promote the learning of architecture through research and collaborative innovation using digital technologies as a means of work and communication between academic and professional participants. The idea is to integrate in the traditional Design Studio a new profile of architect that fits better into the current professional circumstances. This professional profile does not focus so much on whether the architect should have general knowledge or should specialize in a specific area of work. It focuses on two premises: students have to acquire the ability to be more critical, curious and autonomous and to achieve instrumental and social expertise in digital technologies.

The *iLab* project uses a blended approach to develop research projects linked to different fields of architecture (technology, urban planning, energy

[48] A complete documentation of the research findings will only be possible when the study is fully accomplished. However, we think that the presentation of this project in this paper is relevant because it represents the culmination of a research work conducted during the realization of this paper and our above-mentioned doctoral thesis.

analysis, heritage conservation and art) with the collaboration of specialists (from different disciplines) and companies of the AEC sector. It combines on-site activities (master classes, reviews and practice period with professional partners) with online tasks (brainstorm sessions, design presentations and edition of video material). The learning process is supported by a virtual platform with two environments. The firsts hosts different research-based learning activities divided into three areas focus on the creation, documentation and dissemination of diverse graphical and descriptive content. The second is an autonomous and private environment where students can manage their own resources (bibliography, audiovisual material, interviews and reports) to carry out their current and future research projects. The purpose of this personal environment is that students learn to detect, manage and take advantage of the appropriate information available in other projects and the Internet. As a result, students will improve those competences that are related to the management and communication of digital content and to acquire habits based on Lifelong Learning.

The duration of each Digital Design Lab will be different depending on the type of the research project and the academic level. In the degree of architecture, although the projects deal only with theoretical or design aspects, the duration will be at least two semesters (fifteen weeks each) in order to carry out a thorough investigation and to realize the practice period with the partners. The fifteen weeks will be divided into three blocks of five weeks (seminar block, project block and practice block) leaving the last week of each block to perform open presentations.

Finally, the plan is that students adopt the role of entrepreneurs. They will have enough freedom to choose those projects which they wish to develop and investigate. Meanwhile, teachers will assume the task of guiding and accompanying students throughout the entire design and fabrication processes as partners. Professional companies and architectural studios will also play an important role by offering professional advice, sponsoring research projects and providing the necessary resources for the construction or marketing of the proposals.

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