10th International Conference on Higher Education Advances (HEAd'24)
Universitat Politècnica de València, València, 2024
DOI: https://doi.org/10.4995/HEAd24.2024.17336

BIM evolution of architectural teaching

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How to cite: Basti, A.; Di Giuseppe E. 2024. BIM evolution of architectural teaching. In: 10th International Conference on Higher Education Advances (HEAd'24). Valencia, 18-21 June 2024. https://doi.org/10.4995/HEAd24.2024.17336

Abstract
The contribution refers to an experience of integrating IT (information technologies) within the single-disciplinary course of design of construction systems of the second year of the degree course in Architecture of Pescara (IT). The experimentation was conducted in order to verify the potential and limits of the use of BIM (Building Information Modeling) within the architect's training course. On the basis of the results achieved, it was possible to note various advantages brought by the use of these technologies, such as to give rise to some reflections on the scenarios of transformation of traditional teaching methods. Transformations necessary to intercept the educational potential offered by new multimedia project and communication tools, and to meet the ever-increasing demand of the construction and infrastructure european market, especially the public one, strongly oriented towards the digitalisation of processes.

Keywords: *Information technologies; Building information modeling; architectural teaching; building sistems design; digital skills.*

1. Introduction

The digital transition represents one of the main challenges that facing the economic and social system, in terms of simplification and automation of organizational processes, and in terms of information sharing and knowledge dissemination. The progressive integration of computerized data processing tools within traditional analog procedures, requires in addition to in-depth knowledge of the available software, a progressive and careful rethinking of methodologies and processes of analysis and control of results, necessary to ensure the consistency of outcomes respect to objectives. This makes it necessary to implement a comprehensive rethinking of programmatic, design, production and training approaches, so as to build a professional and operational scenario in which traditional skills are complemented by new professional figures, capable of driving and orienting the integration of new technologies. This need is particularly urgent in the construction sector, which over the past decades it was particularly affected by instances of change, toward greater and more efficient evolution in terms of digitalization, industrialization and sustainability of design and production processes.

2. Background

A concrete demonstration of this situation, is the strong push implemented by most member states of the European Union toward progressive digitalization of the sector (European Construction Sector Observatory, 2021). Push based on the three pillars consisting of the digital data acquisition (Internet of things, 3D scanning), the automating processes (use of robots, 3D printing and drones), the Digital information and analisys (BIM-Building Information Modelling, Digital Twins, Virtual and Augmented reality, Artificial Intelligence).The latter one, urges all project disciplines in the AEC (Architecture, Engeenering, Construction) sector to review their methodological and operational approaches, in light of ongoing technological innovation (Paris, 2023) based on policies initiated by national governments, and aimed at integrating BIM-oriented requirements within public procurement (Bolpagni, 2013; Popov et al, 2021). Policies culminated with the adoption of EU Directive 2014/24/EU, Article 22 of which states "For public works and design contests, Member States may require the use of specific electronic tools, such as Building Information Modelling.". A need also reiterated by the Strategic Research & Innovation Agenda 2021-2027, promoted by the European Construction, built environment and energy efficient building Technology Platform (ECTP), which identifies the deployment of digital technologies as the medium-term cross-cutting objective to be pursued (2030 agenda), in order to support policies for energy, ecological, sustainable and inclusive transition of built environment (ECTP, 2019).

Studies conducted at European level confirm that among of the causes of delay of Information Tecnoligies (IT) diffusion, emerges the lack of professionals trained in the use of technologies, especially in the early stages of design, where the use of digital tools could reduce project production time by 50%.

Studies also emphasize the need to change the current design approaches of professionals, in particular of architects, so as to conceive the entire project in a digital, informed and integrated manner (Salgado, 2022). The new experties required by digital transition concerns, in addition to knowledge of IT tools, the ability to coordinate technical skills that converging in digital BIM model (architecture, engineering, energy, sustainability and environment, manufacturing, economics and managent), as well as the management of digital information flows, validation and data security (European Commission, 2019). Studies also highlight the lack of this type of teaching within university courses (Charef et al., 2019), as well as some obstacles and methodological needs for the application of BIM.

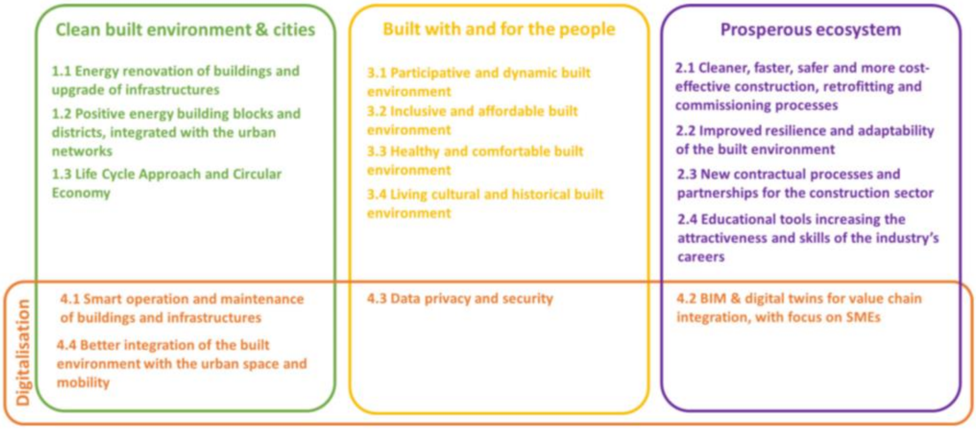

Figure 1. Cross cutting dimension of the Digitalisation with other three objectives . Source:(ECTP, 2019)

2.1. Obstacles

In architecture degree programs, in particular, the use of BIM as early as the first years of the course is seen as potentially negative for students, because it could limit their creativity and take a long time to learn the tools instead of focusing on the project development (Almutiri, 2020). Two aspects in apparent contrast to the traditional conception of teaching, based on the pedagogical value of the design-lab, a place of communication and critical reflection between student and teacher, where students conceptualize their projects and visually represent the answer to the problem. (Green & Bonollo, 2003). However, at the same time surveys show that the students spend more than 65% of their time in the elaboration of traditional 2D method drawings. They starts drawing plans and only after these drawing elevations, sections and 3D views, limiting their three-dimensional perception of project (Almutiri, 2020). Moreover students use simple lines to represent building components (eg: windows, doors, walls) without including detailed information, such as the type of glass or the thermal properties of materials. Traditional method has also additional limitations related to the dependence on drawing skills, the difficulties of moving from conceptual diagram to a detailed design, the necessity to modify all 2D drawings (plans, elevations, sections) every time that will be introduced design changes, the high costs of printing and phisical models production (Salama, 2005; Ostwald & Williams, 2008). All operations that can be performed from the early design stages in the BIM environment (eg. Revit, Archicad, etc.), an interactive, information-rich and implementable methodology.

2.2. Operational approaches

The experiences reported by various universities gives some useful operational indications for understanding the approaches to be taken, in order to achieve a proper implementation of BIM methodology. The first relevant finding is the lack of effectiveness attributed to the teaching of digital technologies carried out in a stand-alone form, as teaching modules in which BIM is considered an autonomous technical tool respect to the " ... treatment of the other topics of disciplinary knowledge ... " (Anderrson, 2013; Sanpaio, 2018). More effective appears the implemetation of a progressive approach to the knowledge of IT for the project, considered as an interdisciplinary subject. An approach that can be start by a training, oriented to the use of tools, and then moving onto their use in disciplinary teaching experiences. Some authors also highlight the importance of articulating the teachings in theoretical seminars and application labs so as to "Mimic the working environment and conditions of real project construction, in order to promote students' ability to analyze and solve problems." (Agirbas, 2020). It is also worth highlighting the aspects of innovation introduced by these teaching methods, which tend to combine specific disciplinary teaching with assisted digital one and with a practice design-lab (Xu, 2018). A teaching model structured according to a multi-year sequence, that starts from the knowledge of 2D graphic tools, passes through solid volumetric modeling to arrive at the construction of an detailed BIM model, which is gradually enriched with new information, according to the logic of the LOD (level of Definition) and LOI (level of Information) introduced by the international standard ISO 19650/2019 and Italian UNI 11337/2007 and followings. A potentiality inherent of digital technologies, due of the possibility of managing all informations in a single virtual environment (the 3D-BIM model), of use this for the prefiguration of functional and spatial incompatibilities (architectural, structural, plant enginnering), of simulating the building's performance (visual, energetic, material, environmental), the construction costs and the facility management activities.

2.3. Feedback

The opinion of the students involved in the experiments is interesting. More than half highlighted the usefulness of BIM as a tool to facilitate the process of understanding and knowing construction systems. Approximately two thirds also noted better operational efficiency, productivity and respect for available times compared to the use of 2D traditional graphic techniques, thanks to the possibility of building the technical elements, and related functional layers, through the use of the parametric libraries and/or of the 3D-objects, developed by the manufacturing companies. Also teachers involved in the training based on BIM confirmed that its implementation helped the students to improve the information contents of their project, their level of knowledge, efficiency and communication, also allowing them to relate the project to the climatic context , to the structural and energy choices, to the materials and products used, in terms of performance and perceptive effects. In addition teachers said that the teaching methodology adopted has reduced the gap between the disciplinary and digital courses, producing an effect of simultaneous knowledge learning (Agirbas, 2020; Almutiri, 2020).

3. Application experiences

The framework of knowledge and operational indications provided by the experiences reported above, has allowed the development of a training proposal oriented towards the integration of information technology within the architecture technology courses of the five-year degree course in architecture in Pescara (IT). This integration concerned the introduction of a BIM-oriented course in the compulsory design of construction systems course in the second year (20 hours out of 100) and the creation of a BIM advanced design course among the disciplines of choice in the fifth year (60 hours). It should be pointed out that in this contribution, for the sake of brevity, the description of the activities carried out in relation to the second-year integrated course only will be developed below. The main objective of the second year integrated course is to accelerate the introduction to the use of a digital 3D approach in the understanding and development of construction solutions from the early years of training, so as to facilitate the overcoming of the limits represented by the complexity of the two-dimensional representation of architecture as much as possible.

3.1. Material and methods

From a methodological point of view, the didactic organisation of the course was divided into an initial 40-hour single-discipline theoretical module, aimed at acquiring knowledge related to the design of building systems. A second module of 20 hours was included to provide basic knowledge of the regulatory framework and related procedural approaches of the BIM methodology. A third module of 40 hours covered the development of BIM-based design workshop executions. At the same time, an additional 30-hour tutoring module was made available to the students, oriented towards the knowledge of BIM tools, in order to enable them to acquire, through the development of elementary case studies, an approach useful for the subsequent development of the BIM-based design workshop.

Table 1. Articulation of teaching modules

Building systems design methods (40 hours)	
BIM methodology (20 hours)	BIM instruments (30 hours)
BIM-based design workshop (40 hours)	←

In particular, in the third teaching module, students were asked to design the construction solutions of a single-family house, defining its structural typology, the overall dimensions of the plant equipment, the stratigraphy of the envelope elements and the performance of the constituent materials. BIM Revit© and/or Archicad© software was used for the development of activities related to the tutoring training module and the workshop. Furthermore, for the parametric design of construction solutions and the technical information of materials and products, in addition to the use of the libraries contained in the two software packages, reference was made to BIM Object databases (www.bimobject.com, www.bim.archiproducts.com, www.bim.cic.hk, www.bimcomponents.com) as well as manufacturers' data sheets. Finally, in order to facilitate the adoption of the new design approach in a digitally informed environment, the construction details of architectural works on the Detail Inspiration platform (https://inspiration.detail.de/projekte.html) were drawn upon.

3.2. Results and Discussion

The experimentation conducted, allowed us to validate what was stated by the studies developed by the other authors mentioned above. It also consented to appreciate how the parallel development of methodological and technical-applicative knowledge (tutoring), allowed students to accelerate learning processes and develop a fair degree of autonomy in the management of digital projects, finding particular benefit in the use of three-dimensional objects for the construction of technical elements. Benefits able to carry out an immediate interference and collision check of individual elements (e.g. beams and columns) directly in the 3D environment, thanks to its spatial visualisation. In this sense, the use of the object libraries, already catalogued by building sub-systems (structures, closures, partitions, installations) allowed them to become immediately familiar with the various types of products used in construction, and with their geometric and performance characteristics, which are shown in the information sheets associated with the individual BIM objects. Even the determination of the functional layers and materials to be used for the construction of the envelope (walls, roofs, etc.) has been made more intuitive by the possibility of combining the layers by subsequent addition into a single multi-material object (e.g. the wall), simply by selecting them from the library. All this while working within the same BIM model, without having to produce the complex quantity of written-graphic drawings required in the traditional 2D method (plan, section, exploded and axonometric views, details, technical data sheets), and thus being able to concentrate more on the design choices rather than on the drafting/editing/continuous updating of drawings..

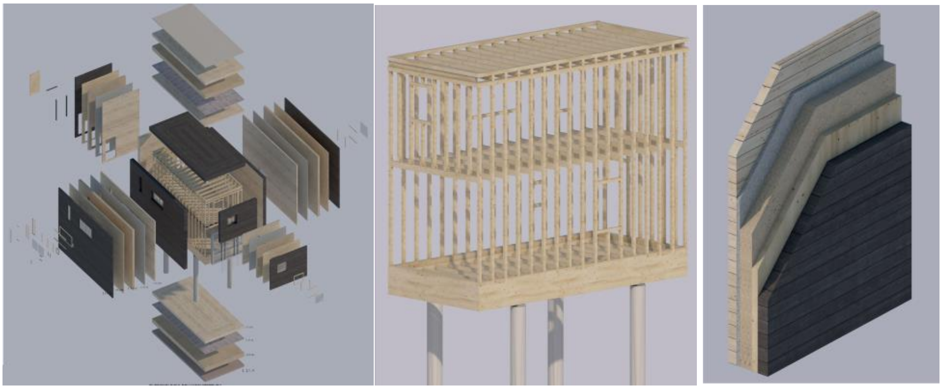

Figure 2. Some results of the design exercitations

4. Conclusions

The results obtained, although limited to the field of investigation of building systems design, highlighted the usefulness and unreliability of the use of IT in the building sector and also challenged traditional methods of project communication, which are too static to be able to render contemporary information complexity. They did, however, provide useful pointers for the development of the subsequent training courses in the fifth year (BIM advanced design course) in which approaches oriented towards structural, energy and environmental simulation and their disciplinary connections will be applied, or alternatively, to the temporal planning of interventions (4D), cost estimation (5D), management and facility management in the building life cycle (6D) and sustainability (7D).

Author Contributions

Conceptualization, AB; methodology, AB; formal analysis, AB and EDG; investigation, AB and EDG; writing-original draft preparation, AB; writing-review and editing, AB; visualization, AB and EDG; supervision, AB. All authors have read and agreed to the published version of the manuscript.

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