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PAPER

Scenarios of Building Information Modelling-Based Design Education in Architecture Schools

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ABSTRACT

Due to the rapid development of computer technologies and trends in digital design, including building information modeling (BIM) and its diffusion into architectural design practice, it was necessary to introduce BIM into architectural curricula in order to prepare students for practice. This article therefore aims to identify scenarios for teaching BIM to architecture students worldwide. To achieve this objective, a thematic analysis of BIM teaching experiences in several selected academic institutions was conducted. The data studied included published articles and official university websites dealing with BIM teaching. A theoretical framework for BIM education was determined, comprising two aspects: pedagogical methods for BIM education and specifications for BIM courses in architecture programs. The document identified several scenarios for teaching BIM in multidisciplinary or architecture-specific courses. BIM teaching can be offered as part of a single course integrated with other courses, or as a separate course. It may be taught as part of related or unrelated courses. Related courses can be organized in parallel with an academic semester, or over several semesters. In addition, there are different types of input to project-based BIM teaching, such as a new design project, the results of a previous design course or an actual project. These scenarios can serve as a reference for universities wishing to integrate BIM into their programs.

KEYWORDS

architecture schools, building information modeling (BIM), BIM teaching scenarios, course integration, higher education

1 INTRODUCTION

Architectural design is one of the disciplines that has been positively influenced by computer technologies, laying the foundations for what is known as computer-aided architectural design (CAAD) [1]. Digital tools are no longer just representation tools, but have become essential elements of the design process [2], such as the use of CAD models with simulation programs for building energy performance [3]. The architectural design process has gradually become digital, particularly with the adoption of

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building information modeling (BIM) as a design approach [4]. The transition from computer-aided design (CAD) to BIM in the early stages of digital design is not limited to the application of three-dimensional modeling, but is gradually moving towards the association of more design information with the three-dimensional model. In many advanced countries, BIM-based design has become mandatory [5]. BIM is defined as a technology based on a digital model, connected to the project database, which aims to reintegrate design, construction and project management. It increases the efficiency of the design and execution process, reducing project delivery times and costs [6]. The use of BIM makes it possible to present architectural, structural, mechanical, electrical and plumbing models in three dimensions, and then use BIM to simulate time planning, construction stages and cost estimates. It is a system that collects and stores all information relating to architectural design, structural design, construction specifications and stages, as well as the design of engineering services, and uses it throughout the building's lifecycle [7]. The Royal Institute of British Architects (RIBA), the Construction Project Information Committee (CPIC) and Building Smart have jointly defined BIM as a "digital representation of the physical and functional characteristics of a facility, creating a shared knowledge resource for information about it and providing a reliable basis for decisions throughout its lifecycle, from design to demolition" [8].

BIM affects professional practice by helping to achieve more productive and creative architectural projects. It is therefore considered one of the most important developments in the field of architecture, engineering, construction and operations (AECO), whose main benefits can be summarized as follows [9]:

1. BIM improves design quality by providing construction information that facilitates visualization, building performance analysis, simulation, communication and final production of design results.
2. BIM supports the construction workflow, reducing project costs, detecting conflicts through the intersection of information between disciplines, proposing solutions and improving the design model.
3. BIM reduces errors, cuts construction time and improves the performance of architectural projects compared with projects not supported by BIM.

The importance of BIM in architectural practice lies in the fact that it provides the aforementioned information. This article therefore focuses on examining how BIM can be integrated into architectural education. A case study of selected universities that teach BIM has been carried out. A thematic analysis of data collected from published articles and university websites was carried out. Key aspects of BIM teaching were highlighted, and different BIM teaching scenarios were identified.

The paper is organized as follows. Section 2 reviews previous studies on the use of BIM in architectural education. Research objectives and methodology are defined in Section 3. Section 4 presents a survey of university experiences in BIM education. Section 5 presents a comparative analysis of BIM-based pedagogies in architecture schools. Section 6 provides the results, Section 7 presents a discussion of the findings and Section 8 concludes the study.

2 USE OF BIM IN ARCHITECTURAL CURRICULA

The main objective of architecture school programs is to equip students with the skills needed to practice their profession in the future. Educational institutions must strive to provide students with the knowledge and skills required by the construction industry.

Integrating BIM into architecture, engineering and construction (AEC) does not change the focus or content, but does require a change in teaching methodology. The American Institute of Architects (AIA) has presented building information modeling as a "catalyst for rethinking architectural education" because of the urgent need to strengthen the link between university education and subsequent professional practice [10]. BIM is not just a design tool, but a revolutionary approach to design. Students learn BIM not as a design tool, but as a non-linear way of thinking, and learn to integrate and use multiple pieces of information simultaneously [11]. The introduction of BIM into the curricula of many architecture programs is the subject of divergent opinions, with BIM seen as a threat to innovation and creativity [12]. These opinions confirm that BIM is an obstacle to creativity and a threat to the exploratory nature of architectural education, as it can prevent the exploration of design alternatives by focusing on teaching the tool. They believe that the use of BIM can reduce the quality of design solutions [13].

On the other hand, there are many proposals concerning the benefits of adopting BIM in architectural education, representing an opportunity to develop and improve architectural education. It enables the use of complex conceptual thinking and the exploration of all dimensions of proposed architectural design [13]. Aksamija found that the pedagogical method of teaching BIM can enable students to integrate different digital tools into design actions and processes, facilitating the rapid adoption of BIM education in architecture programs. She confirmed that BIM is not a threat to the development of students' imagination and creativity. On the contrary, BIM's digital tools can foster design exploration and improve representation skills [12].

The main benefits of introducing BIM into architectural education are as follows: BIM can help bridge the gap between the classroom and real-world professional practice. It can facilitate the teaching of traditional design workshops and other courses that have emerged as a result of industry developments [9]. BIM also encourages collaboration between different disciplines [14]. It helps students make decisions about the economic objectives of projects. BIM helps to understand the impact of the proposed design on the natural environment [13]. It also offers students a platform for new and innovative design ideas. It reduces project completion time by revealing contradictions [14]. BIM simulates a realistic environment, familiarizing students with construction components and details before they embark on professional practice [9]. BIM makes it possible to consider the entire life cycle of a project, from design to use [14]. Finally, BIM supported by virtual reality in plumbing helps students visualize plumbing fixtures and learn integrated design in an innovative way [15].

Despite the benefits of integrating BIM into architectural education, there are a number of obstacles that can hinder the integration of BIM into architectural curricula. For example, they may be due to a lack of knowledge among educators and academics about the BIM approach and a lack of familiarity with the use of its IT tools. In addition, they result from the inability of programs to integrate new courses due to time constraints. Finally, they result from insufficient technical resources (computers and software) available for student training [14].

Numerous studies have proposed various perspectives on the integration of BIM (Building Information Modeling) into educational programs. The design teaching studio is influenced by the emergence of IT tools and their impact on the design process, particularly BIM. Since 2006, Ambrose has established design studio teaching methodologies using BIM, which offers an integrated process for design and construction, supported by simulation and fabrication tools. It proposes the possibility of starting a design teaching workshop with a building, rather than the traditional approach that ends with the design of a building. In 2012, a design education workshop model was proposed, based on BIM methodology, establishing reproducible relationships

between design and data-driven designs, as well as collaboration between disciplines involved in the design process [16]. Nakapan believes that, in every stage of education, the design studio has a certain level of BIM detail and drawings. In the first year, the focus of BIM is on conveying the building's shape, while construction details are at a minimum [11]. Zieliński & Wójtowicz point out that BIM teaching in educational curricula occurs at three levels, taking into consideration the duration of university courses. The first level introduces students to BIM technology. The BIM course is connected to other courses, especially those related to construction. It is implemented in the conceptual design stage with general information about the construction and materials used. The course output is 2D documents without detailed 3D model solutions. The second level concentrates on teaching interdisciplinary collaboration. Detailed 3D models are presented focusing on material specifications and quantities. The third level focuses on building operation and servicing and environmental simulation. It helps students to learn about intelligent building systems and how BIM technology can be used to manage a building throughout its life cycle [17].

Laovisutthichai stresses the importance of integrating BIM into the structure of the curriculum and the core design studio. He proposes restructuring Chulalongkorn University's architectural design program and introducing BIM at three levels: introductory, practical and advanced use. BIM is integrated into the CAD innovation, architectural design and construction technology courses, and linked sequentially throughout the academic year as an option for students [9]. Agirbas's study presents an experiment to introduce BIM through three sequential and compulsory building science courses for architecture students at Fatih Sultan Mehmet Vakif University in Istanbul, which are traditionally taught. The study found out that teaching construction courses with this new methodology help students understand the building system easily. Students are introduced to BIM software at the beginning of the course and choose Revit software for application [18]. Isanovic and Çolakoglu have conducted an experiment on teaching BIM to master's students through an elective course, which prioritizes self-learning and a student-centered approach. Students learn the required skills independently and adopt a flipped classroom teaching strategy. The course relies on exchanging experiences with the professional community and is offered by a specialized engineering company that employs BIM in professional practice. The course includes lectures followed by exercises, with students divided into cooperative teams [6]. Cuperschmid and Castriotto's study propose introducing BIM into architectural and urban engineering courses at Campinas State University in Brazil. BIM is introduced in the second year as a compulsory course, and the study suggests using a blended learning approach. The introductory course covers a conceptual introduction to BIM, interdisciplinary compatibility, digital geometric modeling, parametrization, element category definitions and 2D technical representation. At the end of the course, students apply BIM methodology to a small residential project [14].

It is clear from the above that it is very important to include BIM in architectural curricula, as this will enhance and develop architectural education and strengthen the link between practice and teaching. However, there are no specific methods for integrating BIM into the architectural curricula that universities wish to offer. Indeed, previous studies have shown that different teaching methodologies are used and that the content of the courses offered is varied.

3 RESEARCH OBJECTIVES AND METHODOLOGY

The increasing adoption of computer technologies, especially BIM in the design and construction of projects has led universities to develop teaching methodologies

in architecture schools to suit these continuous developments. However, there are no specific ways to integrate BIM in the architecture curriculum. Therefore, the research aims to explore the methods of incorporating BIM in architecture programs. In addition, the paper seeks to identify scenarios of teaching BIM to be a guide for universities that want to integrate BIM into their curricula. The research questions are: what are the main aspects of pedagogy and curricula in BIM courses at architecture schools? And, what are the common scenarios of teaching BIM? To answer the research questions, the paper has relied on specific case studies which belong to various universities that adopt BIM teaching in their curricula. A thematic analysis of the data available through published papers and official university websites has been conducted to extract a framework that defines teaching BIM in universities and to suggest different scenarios for teaching BIM. However, the research limitation is the sample size of the investigated universities which can be attributed to the limited access to information. Figure 1 explains the stages in the methodology used in this article.

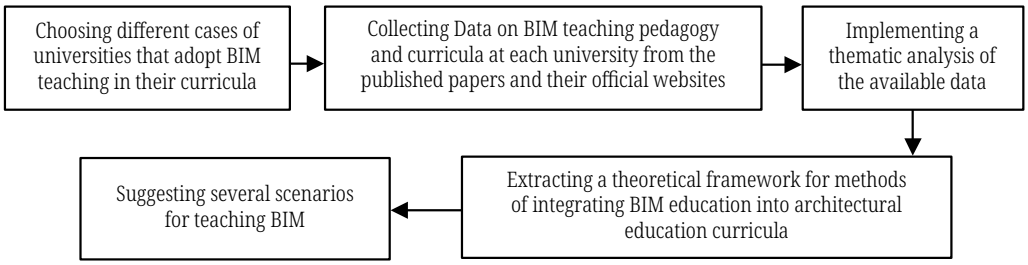

Fig. 1. Research methodology

4 SURVEY OF UNIVERSITY EXPERIENCE IN BIM TEACHING

The case studies were selected from different countries according to the availability of information on their BIM courses. The sources of information adopted by the research are published articles and official university websites. In addition, the selected universities implement diverse and varied BIM teaching methods. The requirements and pedagogies of BIM courses at the universities studied are described in the paragraphs below.

The School of Architecture, Planning and Policy Development at the Institute Technology Bandung in Indonesia offers BIM education to undergraduate students in two courses. The first course is the Architectural Computing Studio, which is compulsory for students in the second semester of their second year. This course introduces students to BIM concepts, its basic principles, component modelling fundamentals, and data extraction to achieve an understanding of object representation. Students then apply their acquired knowledge to an individual design project, presenting it with extracting component tables. The second course is an elective in the third or fourth year, presenting both the architectural BIM methodology and the collaborative BIM methodology. The architectural BIM methodology focuses on introducing the advanced Autodesk Revit software for architectural design, while the collaborative BIM methodology emphasizes implementing collaborative aspects between architecture and other disciplines: structural and mechanical, using Autodesk Revit. Academics collaborate with industry partners to deliver and develop contents for the second course, exposing students to real projects that use collaborative BIM. During the course, students complete two exercises. Figure 2 explains the first exercise, which is on the individual level, consisting of using BIM to redesign the output

of a student's previously completed design studio project and to provide quantity tables for it. The second exercise, which is at the team level, the industry partner presents a real design project, asking students to redesign it and then detect clashes between architectural, structural, and sanitary components [16].

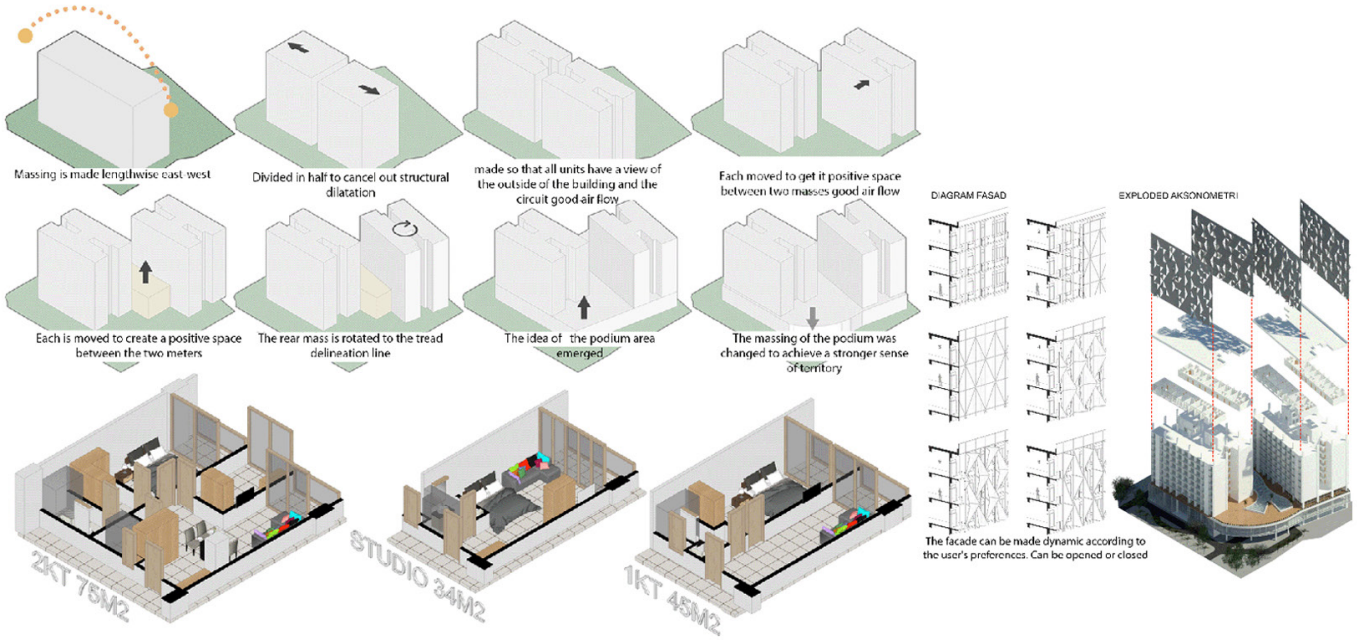

Fig. 2. An example of a student project using BIM in its design [16]

It is evident from what has been said above that it is possible to teach BIM in a compulsory as well as an elective course. There is a variety of knowledge offered, such as methods of representing building components in BIM, preparing schedules of building components and their quantities, and clash detection between designs of different disciplines. In both BIM courses, a project is adopted for applying the acquired knowledge during the course. The projects adopted in BIM education vary from the projects designed by students in previous courses, real projects, and course-specific projects. In addition, it is possible for a course instructor to rely on professional practitioners as lecturers in a BIM course. A second experience in teaching BIM is found in the Faculty of Architecture at the Czech Technical University in Prague. BIM is taught to undergraduate students in their first year as a mandatory part of the curriculum for two semesters. Basic skills are taught within the BIM 1.0 level using (Revit and ArchiCAD) software, which include 2D and 3D modelling and the derivation of geometrical shapes. BIM is taught to the second-year students as elective course for two semesters. The first focuses on building materials, components, and 2D representation using the Revit software. On the other hand, the second semester covers topics such as parametric modelling, project organization, interdisciplinary collaboration, clash detection, and others. In the following years, the integration of BIM into educational curricula has been developed. In the first year, options for teaching Revit (BIM) and ArchiCAD (BIM) are provided, without students having any prior knowledge, as well as offering the option to use BIM in the design studio in the same semester. In the third year, BIM is used integrally in the design studio as an optional component in the graduation project, where students work on creating a simplified model for heating, ventilation, air conditioning, plumbing and insulation of load-bearing parts of the designed building, in addition

to clash detection [19]. The Design Computing I – BIM course is taught as an elective course for postgraduate students in architecture and urban curricula [20]. The course provides information about BIM projects, methods of information sharing, the use of BIM in sustainable development, zero-energy buildings, clash detection methods, and others [21].

Based on the aforementioned, it can be said that various methods for employing BIM in educational curricula can be applied. BIM courses can be offered to undergraduate and/or graduate students, as a mandatory or optional subject. In addition, BIM can be introduced as a part of the syllabus of other courses such as the design studio or architectural representation courses. The students have the option to apply BIM in the design studio projects and the graduation project. The integration of BIM courses may be either sequential or non-sequential.

At the University of Massachusetts Amherst, in the first semester of the second year, digital technologies related to visual representation and graphic design are presented in addition to BIM software, specifically Rhino and Autodesk Revit. Students learn basic 3D modelling techniques by modelling simple geometric shapes in Rhino and are applied to a case study model of a house. Then they learn how to move out 3D models designed in Rhino to Revit, to create simple blocks and build elements in Revit. The course relies on the teacher to provide knowledge to the students and an online repository is used to share final assignments [12]. During the second semester, students begin to develop their Rhino modelling skills and work on their design studio project (from the previous semester) to model 3D representations of their designs. Then, students begin to model their building in Revit and prepare design documents (floor plans, sections, elevations, and 3D perspectives). This course allows students to simultaneously develop skills in design and digital representation, successfully using complex BIM tools to express architectural design [12]. In the Faculty of Architectural Engineering at Cracow University of Technology (FA-CUT) in Poland, BIM is incorporated into undergraduate curricula through the Design Techniques course [22]. It is offered during the second semester of the first year and culminates in an individual student project with BIM Level 1 maturity and some elements at BIM Level 2. Students use the ArchiCAD program. The tutorial lessons in the classroom provide guidance for students in their designs, supported by e-learning software. In later years, the curriculum has been modified to introduce new tools related to BIM techniques and to link the course with design and structural engineering courses [17]. BIM continues to be offered through the Design Techniques course in the first semester of the second year [22]. In addition, the university also offers a BIM Computer Techniques I-C-6 course in the second semester of the master's program which is a professionally recognized degree by the Polish Accreditation Committee, the European Union, and the Royal Institute of British Architects (RIBA) [23].

As demonstrated above, BIM can be integrated into curricula through digital technology courses or offered as specialized BIM technique courses. These courses can be linked with other courses, such as design and structural engineering courses, and can be supplemented with e-learning software.

The University of Nottingham in China offers a separate BIM module for final-year undergraduate AEC students, in which students from Architecture, Engineering, and Construction disciplines work together in groups. This collaboration also extends to graduate students. Most students have prior academic and professional experience before entering the BIM-based design groups. The course begins with intensive software skills training, including Autodesk Revit and Navisworks. Students are guided to use BIM as a digital platform for a joint project design, in addition to

using energy simulation software with BIM. Architecture students become familiar with details outside their specialization such as learning concrete construction in Revit Structure, and learning how to integrate building service (such as air conditioning and heating) within the building's structural system. The BIM module aims to focus on adopting BIM tools to enhance a multidisciplinary design by constructing a model encompassing architectural, structural, and construction services elements, and linking the design proposal to construction scheduling, cost, and building sustainability in a specific path. Students apply this approach to a real project, where the requirements include architectural presentation, cost estimation, construction scheduling, and the integrated digital model [24]. Newcastle University in Australia also adopts an interdisciplinary collaboration approach, but within a course in the Department of Architecture and the Built Environment. The university offers the course "Communication in Built Environments," which is a core subject for students from three disciplines to optionally enroll: architecture, construction management, and industrial design. The course facilitates the teaching of theoretical concepts and technical skills. Before enrolling in the course, architecture students must complete a basic digital communication course. The course is based on real-world local projects that use BIM to help students understand the basics and importance of collaborative work, aiming to introduce BIM into architectural design practice, and providing design fundamentals and collaboration through BIM. Participants are asked to complete a small collaborative design project over seven weeks using ArchiCAD as the primary BIM system, supported by Web 2.0 technologies for communication and collaboration [25].

The above examples of teaching BIM demonstrate the university's capability to offer BIM through a separate module for various academic disciplines besides architecture, and for both undergraduate and graduate students together. Prerequisites for entering the course are a prior experience with BIM in the case of Nottingham University in China or completing specific courses in the case of Newcastle University in Australia. Real projects are used as BIM case studies to both acquire and apply the knowledge. Additionally, the course can be offered for BIM alone or combined with environmental simulation methods.

Penn State University in the United States organizes a one-semester BIM course, offered to third, fourth, and fifth-year students and graduate students as an elective. Groups of six students from different disciplines: architectural engineering, landscape engineering, construction engineering, mechanical engineering, and lighting/electrical engineering disciplines, are formed with a requirement of prior knowledge of BIM programs for enrollment. Students are tasked with redesigning a project aimed at sustainability. The course begins with lectures on "Integrated Design and Building Information Modelling (BIM)," "Sustainability and Green Building Information Modelling," and "Teamwork," supported by e-learning websites. The course is conducted in the Immersive Construction (ICon) Laboratory, which provides an immersive and tangible viewing environment. At the end of the course, the final project is presented, including architectural design, landscape engineering, energy analysis, cost estimation, and construction scheduling, including 4D modelling, constructability, and clash detection [26]. The University of Vienna in Austria relies on "project-based pedagogy" to offer a separate, interdisciplinary design studio called "Multidisciplinary Design Concepts Using Building Information Modelling (BIM)". The course is offered as an elective to undergraduate students and lasts for one semester. Students are expected to have prior knowledge of BIM techniques and choose the technology that suits them best for application in the course project. Students from various disciplines (architecture, civil engineering,

and construction sciences) collaborate on a comprehensive, interdisciplinary design project. The course emphasizes collaboration in the primary aspect and focuses on the use of architectural BIM tools in the secondly aspect, particularly in the design of facades and new functions. The design teams' task is to develop an integrated preliminary design, consisting of architectural and functional design, structural design, as well as HVAC and energy design, in addition to the use of simulation and optimization tools. The course integrates digital design methodologies, BIM and simulation [27].

It is evident from what has been said above that project-based BIM learning can be introduced at various academic levels for undergraduate and postgraduate students across various disciplines. In addition, multiple digital design technologies such as simulation and virtual reality are integrated in teaching BIM. Both lectures and electronic educational websites are used as sources for knowledge.

In Turkey, Yildiz Technical University offers a BIM education curriculum through the introductory computer science course MIM2082 for second-year undergraduate students as a compulsory course within the school curriculum. The course teaches BIM to beginners, enabling students to communicate with various stakeholders related to their projects and access relevant information, such as statistics, and so on [28]. At Istanbul Technical University in Turkey, the "Design Together" competition is organized to promote collaboration among students and introduce them to BIM. The competition involves three disciplines (architecture, civil engineering, and mechanical engineering) in a design team format. Students receive brief training on BIM software and collaboration concepts, then, they are challenged to design a student center project on the university campus with the condition of integrating sustainability, energy efficiency, and renewable energy into the design. At the end of the competition, students present architectural, structural, and mechanical BIM models, perform sustainability analyses, detect clashes between models, and provide a 4D model illustrating the construction process sequence and cost [29].

It is apparent from the above that BIM can be taught to students through competitions involving architectural, civil, and mechanical engineering disciplines to enhance collaboration among them. Design teams are formed to work on a specific project, in addition to the potential of using BIM to achieve sustainability goals.

The next section identifies the main aspects of BIM education in the investigated universities.

5 COMPARATIVE ANALYSIS OF BIM-BASED PEDAGOGIES IN ARCHITECTURE SCHOOLS

It is clear from the previous section that there are differences in the pedagogies applied by universities to BIM courses, with a particular emphasis on multidisciplinary collaboration. BIM courses are offered in the classroom or online by faculty members or professional practitioners to undergraduate or graduate students. They are presented as formal or non-formal education programs. They are compulsory or optional courses, taken by a single participant or by a group of participants. BIM courses are offered separately or integrated with other courses. For example, design workshop courses can be dedicated to BIM instruction. In addition, prerequisite courses or prior knowledge and skills are required, such as students' mastery of specific BIM software.

Table 1 shows that six out of ten universities teach BIM in multidisciplinary courses. Most universities use face-to-face courses to teach BIM. Seven out of ten

universities use faculty members rather than practitioners to introduce BIM courses. Four out of ten universities offer BIM courses to undergraduate and graduate students. Most universities rely on formal education programs to teach BIM. Six out of ten universities teach BIM as an elective, and BIM is integrated into other courses. In addition, six out of ten universities rely on group participation. Finally, in six out of ten universities, BIM courses require no prior knowledge.

Table 1. Summary of the most important aspects of BIM teaching in selected cases

Aspects of BIM Teaching	Institute Technology Bandung	Czech Technical University	University of Massachusetts Amherst	Cracow University of Technology	University of Nottingham in China	Newcastle University in Australia	Penn State University	The University of Vienna	Yildiz Technical University	Istanbul Technical University
Multidisciplinary Course	√				√	√	√	√		√
Architecture Specific Course	√	√	√	√					√	
Classroom or Studio-based Learning	√	√	√	√	√	√	√	√	√	
E-learning			√	√			√			
Introduced by Teachers	√		√	√	√	√		√	√	
Introduced by Practitioners	√				√	√		√		
Attended by Undergraduate Students	√	√	√	√	√	√	√	√	√	√
Attended by Postgraduate Students		√		√	√		√			
Formal Education program	√	√	√	√	√	√	√	√	√	
None-Formal education program										√
Compulsory Courses	√	√	√	√					√	
Elective Courses	√				√	√	√	√		√
Attended by Single Participants	√	√	√	√					√	
Attended by a Group of Participants	√				√	√	√	√		√
Separate Course	√	√			√		√	√		√
Integrated with other Courses	√	√	√	√		√			√	
Prerequisite Courses or Prior Knowledge					√	√	√	√		
No Prerequisites are required	√	√	√	√					√	√

6 MAIN RESULTS

Taking into account the previous literature review and the experiences of universities in teaching BIM, it can be said that there are a variety of methods of teaching

BIM in architectural education programs. These differences can be divided into two categories: the pedagogical methods of BIM teaching and the specifications of BIM courses in departmental programs. The pedagogical methods of BIM education, specified in Table 2, differ in terms of the sources of knowledge provision, such as the teacher-centered approach, the student-centered approach, or both. The place of learning can be realistic in a classroom, studio or laboratory, or virtual in e-learning. Learning methods include the introduction of BIM principles, case studies or a project. In addition, trainers can be faculty members, practitioners, software developers, etc.

Table 2. Key aspects of BIM teaching: Pedagogical methods

The primary aspect: Pedagogical Methods in BIM Education	**1.** Type of Pedagogical Methods	Pedagogy according to the source of providing scientific knowledge	Teacher-Centered Approach to Learning	
			Student-Centered Approach to Learning	
			A Mixture of the two	
		Pedagogy depending on the place of learning	Learning in the classroom, studio, or lab	
			e-Learning	
			Blended learning between classrooms and e-learning	
			etc.	
		Pedagogy depending on the learning method	Introducing Design Principles Using BIM	
			Analyzing Case Studies	Realistic projects
				Virtual projects
			Applying to a Project method	Design dedicated projects for the course
				Re-designing previous design studio projects
				Redesign realistic projects
				Other
			Other	
	2. Methods of conveying knowledge to students		Presenting lectures	
			Watching educational videos	
			Other	
	3. Knowledge providers		Teachers at the university	
			Practitioners (experts in BIM)	
			BIM software developers	
			Other	

The specifications of BIM courses within the curricula, clarified in Table 3, show differences in terms of course timing as a formal or informal education program. In addition, BIM can be offered in one course only, or more than one course. Also, different types of knowledge content related to architecture discipline or multiple disciplines are delivered. Course attendants can be a single student or a group of students. These courses are compulsory or elective which may have previous prerequisites.

Table 3. Second aspect of BIM teaching: BIM course specifications

The secondly aspect: specifications of BIM courses within the department's curricula	**1.** Timing of BIM education in universities	Adopting it within the curriculum of specific academic years	Undergraduates only	
			Postgraduates only	
			Both undergraduate and postgraduate	
		Adopting it separately from the academic years curriculum (informal education activities)	Competitions	
			Workshops	
			Training courses	
			Separate BIM module	
			Other	
	2. Adopting BIM in architecture school syllabus	Introducing BIM in one course only	Integration into an existing course	Architectural Design course
				Architectural representation course
				Design techniques course
				Building construction course
				Other
			A separate course within the curriculum	
		Introducing BIM in more than one course	Type of courses	Software education course
				Architectural design course
				Environmental design course
				Building construction course
				Other
			The relationship between BIM courses	Sequential courses within one academic year
				A synchronous parallel course within one semester
				A sequential course within more than one academic year
				A non-sequential course within more than one academic year
	3. The type of knowledge content of the course	Knowledge about architecture		
		Knowledge about related engineering disciplines	Environmental problems	
			Structural problems	
			Mechanical engineering services	
			Electrical engineering services	
			Other	
	4. Participants in the course	Single Participant		
		Participation of several students in groups	Architecture students only	
			Architecture students plus students from other disciplines	
	5. BIM course admission and registration	BIM course registration requirements	Previous prerequisites	
			No previous requirements	
		BIM Course admission options	Compulsory	
			Elective	

7 DISCUSSION

Based on the above sections, we can deduce the most common scenarios in BIM teaching. Firstly, a BIM course may be multidisciplinary, bringing together students from several scientific departments such as architecture, civil engineering, design management, etc., or it may be an architecture-specific course. Secondly, BIM teaching can be categorized as follows according to the relationship between the various BIM courses:

- BIM is taught in a single integrated course within other courses such as architectural design or building construction, or it is taught in a separate independent course.
- BIM is taught in multiple sequential courses over more than one academic semester, starting from courses such as teaching BIM-based design software or teaching BIM design principles, and ending with a BIM-based design course.
- BIM is taught in multiple simultaneous parallel courses within a single academic semester, including a course teaching BIM-based design software and a BIM-based design course.
- BIM is taught in multiple unrelated courses, such as environmental design based on BIM and engineering services design courses, among others.

Thirdly, from the experiences of teaching BIM in several universities, it can be seen that the inputs of the BIM-based design courses vary in terms of the project being designed, as follows:

- In the case of integrating a design course with a BIM course, a joint project for both design and BIM teaching is adopted.
- In the case of separating the design course from the BIM course, there are three options: the outputs of a previous design project for each student are adopted as an input to teaching the BIM course, the output of a real project is adopted as an input to teaching the BIM course, or a dedicated virtual project is adopted for the BIM teaching course.

8 CONCLUSIONS

The growing role of BIM in the architectural profession makes the adoption of BIM in architectural education an urgent issue. This article therefore explores methods of integrating BIM into architectural curricula to equip students with the skills needed for their future professional practice. Case studies from ten universities offering BIM courses in their programs were examined. A thematic analysis of data collected from published articles and official university websites was carried out. A theoretical framework of BIM-based teaching approaches was developed to define pedagogical methods in BIM teaching and the specifics of BIM courses in departmental programs. The predominant approach to BIM teaching consists of face-to-face multidisciplinary courses for undergraduates. BIM courses are mainly offered as part of formal education programs. The document presents some BIM teaching scenarios to enable universities to choose the approach best suited to their programs. BIM courses can be offered in discipline-specific classes or in multidisciplinary classes.

BIM can be taught in a single integrated course, a separate independent course, several consecutive courses, several simultaneous parallel courses and several unrelated courses. Finally, the paper concludes with various contributions for BIM-based design courses. These may be a project common to a design course and BIM, a project from a previous design course, a real project or a dedicated virtual project. Different scenarios for separating a BIM course from a design course can address concerns about the effects of BIM tools on limiting design exploration and creativity.

For future research, the size of the case studies can be increased. In addition, a comparative analysis of course results for different BIM teaching scenarios can be carried out to verify their effectiveness in teaching BIM.

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