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# Developing a BIM Integrated Curriculum Framework for Undergraduate Architectural Education in Libya

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Abstract: Due to the increase demand and enormous potential of BIM adoption in the construction industry around the world, the modern Architecture, Engineering, Construction, and Operation (AECO) industries are seeking to hire engineering graduates with BIM competencies. Throughout the world, Academics in the subject field of AECO within higher educational institutions are devoting time and resources to developing BIM curricula for different educational levels. This paper presents ongoing research into developing a BIM-integrated curriculum framework for undergraduate architectural education in Libya. The described research is conducted through a systematic literature review to gain an understanding of current issues and challenges for academics in order to design BIM curriculum in architectural education. This review can help to develop a novel BIM-integrated curriculum for enhanced architectural education at the undergraduate level. The findings reveal that international academics and professionals consider that educational institutions are vital to facilitating the process of the training of BIM professionals for AECO and also addressing the gap between university output and industry requirements. As a result, there is an urgent need for providing essential education for BIM Approved Graduates at Libyan universities. This research proposes a BIM-integrated curriculum framework for undergraduate architectural education along with the yearly modulation of subjects taught in undergraduate architectural education and related disciplines. The importance of this research is to encourage an initiative to develop a curriculum framework that can assist academics to establish and deliver BIM integrated education with undergraduate architectural education in Libya.

Keywords: Architectural education, BIM, Integrated curriculum, framework, Libya

# 6 Introduction

This paper describes the authors' current research into the development of a BIMintegrated curriculum framework to aid the pursuit of excellence in architectural education by merging BIM knowledge and skills into curriculum design. This introduction consists of four parts, including the research background, research aim and objectives, implications for research and practice, and a short description of the structure of this paper.

## 6.1 Background

**BIM integrated architectural education**. The construction industry is being transformed by the adoption of digital technologies such as

BIM, which presents educators with challenges in incorporating BIM-related knowledge into current higher education practices [1]–[3]. The authors have recently conducted a preliminary literature review in order to have a better understanding of the state of BIM-related higher education. The review is divided into numerous sections, including general requirements and academic initiatives, and the following academic activities have provided significant support for defining the study strategy:

• **General requirement**. The need for BIM to become integrated into higher education arises as a consequence of the requirement to equip future professionals in the construction sector with advanced technical solutions and collaborative skills so that they may be ready to work in the المؤتمر الوطني الثاني **لتطوير مؤسسات التعليم العالي في ليبيا** The Second National Conference For Developing Higher Education Institutions In Libya جامعة بني وليد وعبر تقنية zoom

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industry in the coming years, given that sector construction is facing the unprecedented and dynamic changes due proliferation of advanced to the technologies increasing and environmentalist expectations [4]. BIM has been integrated into architectural education and related subjects in order to develop students' skills and competence [5], [6].

• Academic initiatives. There has been a wide range of academic initiatives to integrating BIM into architectural education and related subjects with an emphasis on curriculum development and planning [2], [7], academic readiness [8], learning outcomes [5] and students' perceptions and requirements [9].

**Research question.** Despite academic initiatives directed towards BIM into higher education, it looks that there is currently a lack of a consent approach to integrating BIM knowledge and skills with the curriculum. Therefore, this paper seeks to answer the following question: How can the required conceptual knowledge and practical skills relating to BIM be effectively integrated into the undergraduate architectural curriculum?

### 6.2 Aim and objectives

To answer the research question, this paper aims to describe a BIM-integrated curriculum framework for undergraduate architectural education in Libya. This framework has the potential to help academics facilitate the incorporation of BIM education within architectural programmes in Libya, to fully prepare future architectural professionals. Under this overall aim, this research has the following two objectives:

• To systematically review academic initiatives related to BIM education with a focus on curriculum design, course implementation, BIM competencies, and teaching BIM within defined academic levels. • To propose a BIM-integrated curriculum for undergraduate architectural education in Libya

## 6.3 Implications

The research described in this paper should contribute to the existing body of knowledge by providing a better understanding and method on value-oriented BIM technology in the context of architectural education. The implication of this research is the provision of a new BIMintegrated curriculum framework capable of assisting academics to facilitate the integration of BIM into the architectural curricula at the undergraduate level in Libya. This can then assist the university to prepare competent graduate architects to meet the expectations of the construction industry.

Although this framework is limited to architectural education in Libya, it can also serve as a guide for other educators who are attempting to construct a comprehensive picture of BIM technology in their existing engineering education domains. They might then develop a more appropriate BIM education approach to address the problems they may encounter (or have encountered) as a result of implementing BIM courses.

## 6.4 Paper structure

From a presentation structure point of view, the remainder of this paper is structured as follows: Section 2 provides the research background in order to justify the research aim and objectives through a review literature review. Section 3 presents the research methodology to describe the implementation process of the systematic literature review. Section 4 presents the finding of the systematic literature review in four subsections, which described the previously identified best practices of BIM-integrated curriculums. Section 5 presents the proposed BIM-integrated curriculum for undergraduate architectural education in Libya with the identification of BIM learning objectives and outcomes. Section 6 provides the conclusion, limitations and further research needed to cover the limitations of this study.

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## 7 Literature review

# 7.1 The integration of BIM with architectural education

Architectural schools need to deal with contemporary changes to the profession, including the proliferations of new materials and styles of construction and assembly management, along with the use of innovative software and analysis tools [10]. This results in the integration of BIM technology within the architectural curricula being a relatively new initiative for university educators, highlighting the more serious challenges faced by its adoption within the industry [1], [11]. Despite the lack of consensus on teaching approaches for implementing BIM into architectural programmes [12]–[14], it is crucial to review and understand the range of global academic initiatives for the integration of BIM within architectural education.

Architectural education at higher educational worldwide has institutions increasingly included BIM in their curricula, usually either treated as one of several themes in standalone courses, or where BIM modelling is included as a capstone project. Typically, a student studies only one or two topics related to BIM throughout their undergraduate years [2]. As a result, exposure is frequently limited to developing fundamental BIM modelling skills. This is largely because many academic staff lack the practical experience to teach BIM effectively [9]. To close this gap, universities rely on external lecturers or associated academics who are BIM industry specialists [15].

Nevertheless, the number of courses or themes remains restricted, and current architectural educational provision falls well short of driving BIM integration in order to meet current industrial demands [15]. As a result, in an educational environment where few BIM-related themes are introduced to the curriculum of established architectural departments, it is unsurprising that students who take these courses are unable to comprehend BIM application in real-world, project-based problems. Due to the constraints of teaching several themes in a limited amount of time, most curricula are structured in such a way that they cannot provide in-depth and balanced courses on BIM theory and practice [2].

To adequately address these issues, it is necessary to develop entirely new architectural curricula that incorporate advanced digital technologies such as BIM with traditional architectural courses, and students should be selected and trained to reflect the current development. Ideally, industrial professionals should be involved in the new curriculum design process [16], transforming students into a real-world project-based learning workforce capable of undertaking the practical duties necessary in the industry upon graduation.

# 7.2 The importance of BIM for architectural education

The construction industry. which has traditionally been seen as resistant to change and the timely adoption of new technologies, performs badly in comparison to other sectors, such as the aerospace and automotive industries. However, significant efforts have been made in recent decades to facilitate a digital transition marked by the increased use of information technology [17]. BIM technology is critical to this digitalization of the built environment, and efforts aiming at further digitization of the construction sector are becoming more coordinated [18]. As a result, BIM alters how architects and engineers conceive and design projects.

The evolution of university engineering education has been affected by industrial and academic technical and ideological developments [17]. In light of new technologies such as BIM, universities must place an focused emphasis on technological development, linked to the expanding roles and responsibilities associated with contemporary construction projects [19], which necessitate the use of sophisticated technology and technical skills in connection to construction modeling and data management software [20]. Indeed, these roles are very diversified and constantly changing,



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rendering them unintelligible for modifying their courses. However, one thing looks certain: the breadth of a BIM professionals' duties requires universities to achieve the proper balance between technology-related knowledge and organizational and process-related knowledge in the instruction they impart to students.

Several challenges are associated with teaching the BIM approaches in engineering education including the educational approach, the evaluation methodologies, the technological environment, the implementation methodology, identifying BIM-related competencies, industry collaborations, and timetabling [21]. Despite BIM educational challenges, it is widely acknowledged that including BIM education within the core curriculum is important for educational adaption to meet real-world employment needs in construction and architectural practice. Effective BIM instruction in academia is believed to be the quickest way to close the gap between education and industry requirements and to accelerate the development of BIM knowledge and skills [22]. The widespread assumption is that foundational education must address the shortage of BIMskilled individuals in order to bridge the divide between BIM and architectural practice.

# 8 Methodology

Due to the significant quantity of literature review that describing academic practices and initiatives in developing BIM curriculum, a systematic review is a preferable approach to obtain a comprehensive understanding of the educational issues under consideration [23]. The authors of this paper conducted the systematic literature review in three stages as follows: (1) identification, (2) screening, and (3) analysis (see Figure 1).

Identification of studies via Scopus and Web of Science Identification Records identified from: Duplicate records removed before screened (n = 21)Scopus (n = 118)Web of Science (n = 15)Records excluded (n = 65)(Excluded due to non-Screening English language Records screened sourced from not peer-(n = 112)reviewed articles, and a publication date within the last ten years) Included Studies included in qualitative content . analvsis (n = 47)

Figure 25: Systematic literature review implementation process.

**Identification stage:** The first step of this research was to search for studies that were deemed relevant to BIM education by the researchers. Searches were carried out in Scopus and the Web of Science, using search terms such as "BIM education", "BIM integrated curriculum", "BIM courses", "BIM learning", and BIM teaching" among others. The search resulted in 15 and 118 records from Web of Science and the Scopus databases, respectively, for a total of 133 records from both sources. After exporting all 133 entries to the Mendeley software to remove duplicate records, only 112 studies were screened in the second phase.

Screening stage: To ensure that the literature review is relevant and reliable, the remaining 112 records were screened in terms of openaccessible in full-text versions, source/ published in English, sourced from peerreviewed articles, and published within the last ten years. Articles that did not address BIM education were excluded. This screening process then led to a total of 47 articles (These articles are including in the references list). In addition, the authors reviewed the remaining articles and only chose those that addressed at least one of the following topics: (a) Design and development of BIM curriculum and its requirements, (b) BIM competencies and learning outcomes, (c) development and





implementation strategies of BIM education courses and its challenges.

Analysis stage: The remaining 47 articles were then subject to qualitative content analysis, to comprehend complex content and manage the difficulties associated with developing a BIM curriculum in architectural education. Addressing the pre-identified research aim, the author read and analysed the full-text versions of the papers and used an iterative and recursive method to codify and analyze the findings in order to apply them to a topic or subtopic relevant to this research. It was through this process that a thorough understanding of the subject under investigation was gained.

Following the processes described in the above stages, it was possible to derive learning outcomes that can help to develop a BIMintegrated curriculum for architectural education at Libyan universities.

## 9 Findings and Discussion

The results of the study addressing the systematic literature review are presented in four subsections below, which described the identified best practices of BIM-integrated curriculums. These sections offer insights for architectural educators when developing BIM curriculum frameworks.

# 9.1 BIM integrated curriculum development

BIM-integrated curriculum development refers to the process of enhancing AEC departments' existing curricula development. Curriculum development entails the application of a variety of strategies, tools, and procedures. The practice of integrating BIM within AEC departments has demonstrated that it can be a more difficult process than just adding new courses to the architectural curricula. A commonly used approach for developing a curriculum consists of five stages: (1) curriculum analysis, (2) objective design, (3) identifying suitable teaching, learning, and evaluation techniques, (4) development of a syllabus application and appraisal committee, and (5) review of the curriculum [24]. These stages can be followed when developing a BIMintegrated curriculum.

Apart from curriculum design for BIM, numerous researches have examined how BIM is integrated within AEC programs and curricula. [25] reported that the majority of architecture schools have integrated BIM within their curricula and associated construction modules, but that most construction schools in their study only used 4D and 5D BIM models to teach scheduling and cost estimating. [26] examined how educational innovations like industry collaborations, multidisciplinary cooperation, and online learning have been integrated into AEC BIM programs. Their analysis revealed that BIM is presently utilized mostlv to teach visualization and constructability activities in AEC programs, and that these are two areas where programs wish to extend their usage of BIM. [27] undertook a comprehensive review of the literature to assess existing techniques for developing BIM curriculum program, explaining how some BIM courses were designed, delivered, developed, and assessed. Additionally, they highlighted challenges associated with supporting BIM education and offered alternative ways for incorporating BIM into the curriculum. The study indicated that BIM has the potential to become an integral component of the AEC industry's disciplines; therefore, several factors prerequisites, aims, including objectives, content, instructional methods, and assessments, must be addressed while designing and implementing BIM curriculum.

Architecture students need to develop a worldwide perception concerning how to deal with the visual, technological, functional, and aesthetic elements of inhabited spaces within the parameters of ecological contexts. Architectural curriculums have been developed to incorporate BIM through a variety of course types, including BIM stand-alone courses, design studio courses, cross-curriculum teaching modules. engineering graphics courses, and integration with current courses [28]. However, providing standalone BIM

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without appropriate follow-up courses undermines students' longer-term subject retention, as there is no possibility for reusing BIM software across many sessions. Additionally, students typically do not continue to apply program skills after completing a single course, and standalone courses may be unsuccessful owing to the students' learning environment being different from that of their AEC classes [2], [29].

Realigning existing modules may also have disadvantages, since present courses cover a broad range of topics, leaving educators with little time to devote to an in-depth discussion of the possible uses of BIM within in-class projects. BIM and CAD impose an extra cognitive strain on users, emphasizing the learning curve of computer commands and skills above fundamental architectural topics [29]. In addition, students enrolled in a cost estimating course thought their understanding of BIM significantly benefited their overall educational experiences. Those who lacked BIM skills, on the other hand, reported having difficulty utilizing BIM tools[30]. Despite these obstacles, BIM courses have been considered to be worthwhile, particularly given the lack of an alternate method at the moment.

Numerous studies have proposed a variety of solutions for overcoming the constraints of independent courses while also incorporating BIM into the current curriculum within basic BIM architecture courses. One strategy is to combine these two approaches [29], enabling students to gain fundamental BIM concepts and skills while also providing them with advanced BIM skills and knowledge via modernized modules of current themes Furthermore, this allows students to use their BIM expertise in the capstone course [2]. This method, however, faces significant obstacles. including requirements for retaining accreditation status and the restricted capacity of architecture programs to adapt their curriculum to reflect market advancements. Additionally, some substantial prerequisites and upgrades are necessary (i.e., software/hardware and classroom equipment) to incorporate BIM into architectural courses, as well as the necessary

follow-up technical assistance, logistical support, and maintenance [7], [30].

A multidisciplinary approach to teach BIM entails bringing together students from many disciplines to reframe challenges beyond conventional limitations, developing solutions that pertain to real-world AEC projects, procedures, and current concerns [24]. In this approach, institutions must modify BIM curriculums for their students so that they can grasp the fundamental ideas and appropriate application of BIM, and study in an atmosphere where cooperation is not just stimulated, but ingrained in the learning culture. This can be instrumental in the subsequent diffusion of BIM into industrial practice, when appropriately qualified students join the workforce with the skills to communicate and share their BIM skills with colleagues.

Several institutions have now implemented BIM in the design studio as a means of introducing students to BIM technologies, with an emphasis on cooperation within and across AEC disciplines [31], [32]. It is currently normal practice for architectural departments to integrate BIM into the design studio, as it enables the capacity to plan, control, and coordinate the entire project from start to finish (in contrast to conventional operations) [33]. This exposes students to new problems encountered in a comprehensive design studio [2], which aids in the acquisition of the necessary breadth of knowledge and skills. While several BIM academic initiatives focused on developing BIM curricula and implementing various methodologies in a variety of AEC disciplines, including construction engineering and management, comparable efforts are lacking in some critical AEC areas (e.g., architectural and civil engineering), which need more research to address the lack of BIMcurriculum integrated development in architectural education.

In summary, the review indicated that there are several BIM academic initiatives focused on developing BIM curricula and implementing various methodologies in a variety of AEC disciplines, including architecture, construction engineering and management. المؤتمر الوطني الثاني **لتطوير مؤسسات التعليم العالي في ليبيا** The Second National Conference For Developing Higher Education Institutions In Libya جامعة بني وليد وعبر تقنية zoom بتاريخ 2021/10/07



However, the current state of BIM education demonstrates that the existing BIM curriculum in higher education does not meeting the minimum requirements of professional practice. On a more positive note, it is important to develop an inclusive curriculum for educating human resources that fulfills industry and academic requirements. A BIM-integrated curriculum should cover the following topics:

- Fundamental notions and knowledge of BIM technologies and processes.
- Application areas in varying construction procedures (such as constructability review, clash detection, communication, visualization and simulation),
- BIM standards and execution planning.
- BIM-based construction project management skills.
- Expandability to other ICT related to architectural and construction practices and software compatibility.

#### 9.2 BIM course implementations

Course designers worldwide have used a variety of pedagogical approaches to ensure that students grasp all BIM notions and processes covered within BIM courses. [34] made significant contributions to the construction engineering education curriculum bv developing a BIM course with a systematic three-stage development approach (preparation, development, and improvement). This course identified education goals and objectives, learning topics, the composition of learning subjects, and evaluation methods related to BIM education for construction management education in Korai. [35] taught BIM via a peer-review approach, including guidelines for the teacher on how to design a course for the student to study and assess their work. The outcomes of this course showed that students gained more detailed knowledge and skills related to 3D BIM modelling and learned from others' works.

After analyzing numerous case studies, [30] made a number of recommendations for BIM education, which emphasized the need for the continuity of BIM education, and the educational advantages of BIM simulation and visualization, noting that students think that pairing BIM courses with real-world examples may help them better grasp BIM applications. [36] described a program-wide application plan for a BIM-supported teaching development program at the University of Technology Sydney (UTS), and emphasized the model-driven nature of BIM. The strategy's central tenet is to promote a more integrated teaching approach and the integration of many separate topics.

BIM education is evolving, and several nations have begun to prioritize BIM education. Educators are attempting to design appropriate curricula and are keen to develop BIM experts, and universities have made many attempts to establish BIM curricula. Kaunas University of Technology (KTU) and Vilnius Gediminas Technical University (VGTU) offer courses that incorporate BIM instruction, specialized in undergraduate and postgraduate education (respectively). KTU's master's degree program has the objectives of teaching professionals and designing and evolving criteria that will govern and organize BIM drafting [37]. At Helsinki Metropolia University of Applied Sciences, an initiative called "OpeBIM" modifies curricula and courses to utilize BIM for the integration of current courses, so as to facilitate collaborative learning across disciplines. Additionally, to address the development of local industrial resources related to BIM practices, the University of Auckland provides BIM courses to undergraduate and postgraduate studies, and participates actively in New Zealand's national BIM education design, implementing various BIM-related courses in national institutions in a gradualist approach [38].

As outlined above, several BIM educators and researchers have already experimented with academic BIM education courses in a range of AEC disciplines using different approaches. Aside from courses designed to advance BIM knowledge and practice per se, some courses have sought to promote awareness and skills in relation to particular dimensions of construction industry activity, such as sustainability. [39] proposed a system for BIM energy modeling based on the Revit tools-based المؤتمر الوطني الثاني **Lidegu مؤسسات التعليم العالي في ليبيا** The Second National Conference For Developing Higher Education Institutions In Libya دامعة بني وليد وعبر تقنية 2021/10/07 بتاريخ 2021/10/07

energy modeling training module, developed and implemented to acquaint architecture and engineering students with the energy modeling process.

Numerous innovative teaching techniques and notions (e.g., open resources, sustainability, industry-academia project-based learning, partnerships, and professor-student cooperation) have been developed and applied in AEC department courses to provide BIM education. These worldwide BIM researchers' work and experiences have created a rich knowledge base that other BIM educators and researchers from different parts of the world exploit. Additionally, these BIM mav experimental experiences in AEC department courses may be leveraged to establish a practical BIM curriculum, furthering the advancement of academic BIM education.

# 9.3 BIM competencies for architectural students

The integration of BIM education into AEC programs has encountered numerous challenges, including defining the proper competency or body of knowledge for architecture students that meet future employment expectations. "Competence" is a phrase that has been widely used in the construction industry to encompass a variety of elements, including knowledge, abilities, and behaviors. A great architecture syllabus must strike a balance between these BIM principles. Existing BIM competence indexes are directed at BIM as used by professionals rather than at the unique requirements of architects and architecture students [40].

To help architecture students acquire BIM competencies, it is necessary to grasp the BIM process in design projects. [28], [41] examined how AEC firms apply BIM workflows in order to ascertain the BIM competencies required of architects. In real-world projects, architects begin by developing a conceptual design, which is then sent to the BIM project manager, who analyzes the necessary information to be included before passing it on to another BIM model manager. Architects must work with contractors and experts to determine the most appropriate technology, technical and building details, and construction. This needs not just BIM expertise, but also critical cooperation and communication abilities.

Architectural education often emphasizes teaching fundamental nonverbal (graphic) communication skills, as well as the use of computers and other technologies necessary for developing an efficient and economic architectural project. Additionally, other skills like research, cognition (analytical and critical interpersonal thinking), relationships (teamwork), and graph, table, and formula interpretation are taught. Students of architecture acquire an understanding of architectural design, building drawings, and material components. Furthermore, they need to be familiar with other disciplines with fundamental knowledge (e.g., structure and energy) and learn about lean building processes and procedures. Nevertheless, undergraduate architecture courses are insufficient in length to adequately train professionals to function as project directors. When incorporating BIM into an architectural program, [5] recommended including the following essential BIM competence for undergraduate architectural students:

- A theoretical understanding of BIM in architecture and design
- BIM for information capture and concept design
- BIM for communication with other disciplines
- BIM as an authoring tool
- BIM analysis and rapid prototyping tool (a move from implicit to explicit solutions)
- BIM in professional practice
- BIM Management skills
- BIM for visualization
- BIM to manufacture

Due to the unique character of the architectural curriculum, students must develop a breadth of knowledge and proficiency in a variety of disciplines and methodologies [26]. This enables them to supervise the whole location and operation of a structure. Due to the complexity of AEC professions, professionals require the



use of ICT to identify the most suitable candidate for a BIM environment.

The studies under review indicate that the introduction of BIM education into architectural programs has encountered difficulty due to the current ongoing challenge of providing students with the entire body of knowledge (BOK) prerequisite for architectural education per se, and for professional competence as an architectural professional in real-world industrial practice. In other words, there is a shortage of systematic understanding and an absence of establishing basic knowledge, skills, and capabilities to successfully deploy BIM within the architectural program to meet the needs of architectural students and the construction industry. What the community of BIM educators, practitioners, and service users require is a BIM body of knowledge (BIMBOK), which can be identified as the whole set of activities, principles, values, terms, concepts, competencies and outcomes that make up a professional field.

# 9.4 Teaching BIM at different academic levels

Much discussion has taken place over how BIM concepts may be integrated into the academic level of the architectural curriculum, centered on whether BIM concepts should be presented at the lower or upper levels of education programs. According [21],а good to implementation approach should be incremental in nature in order to gradually improve community awareness, discover best practices, and learn from mistakes. BIM should thus be initially presented in an existing theme before being applied to other subjects, whether as a specific course or forming an aspect of another topic [42], [43]. The general structure consists of a transformation from an individual to a team or group to the use of collaboration. Thus, the initial years should emphasize developing individual abilities in the design and analysis of a building model, followed by a focus on teamwork and more intricate projects in the second year, and finally, students should practice on a real-world project with a suitably qualified firm in the final year [33], [44], [45].

An effective framework for integrating BIM into Brazilian architecture and civil engineering programs outlines many ways in which BIM may be taught throughout the curriculum and levels. education The framework was established based on three levels: introductory, intermediate, and advanced. The introductory level focuses on the development of BIM modeler and facilitator skills, which are further developed at the intermediary level, with an emphasis on BIM analyst activities, which complement the BIM designer's skills. The advanced level is equivalent to that of a BIM manager or coordinator. Additionally, the framework proposed six distinct course types for teaching BIM at each developed level: standalone course and digital graphic representation (introductory level); building technology and integrated design studio (intermediary level); and construction management and interdisciplinary design studio (advanced level) [41].

While the framework of [41] is an excellent starting point for teaching BIM, it lacks sufficient depth for each level, resulting in an insufficient comprehension of the course material. Another disadvantage of this framework is that it relies on a single teaching method (project-based learning) for all levels, which does not meet the requirements of various courses and (pedagogically) learner needs. This relates to the question of how to link BIM learning results to academic levels. The BIM Academic Forum (BAF) framework classified BIM learning objectives into three categories: (1) knowledge and understanding; (2) practical skills; and (3) transferrable skills. Furthermore, these categories are linked to the UK academic standards for English undergraduate levels 4 to 6 (see Table 1). These programs are used by professionals and students in the fields of construction, engineering, and architecture [46]. However, there is a dearth of expertise at each given level. It is important to extract the needs for learning outcomes related to the practical skills, understanding, and information associated



with BIM/digital construction. Learning should occur at a pace that is acceptable for the student.

academic In summary, level content identification should strike a balance between conventional knowledge and the BIM learning curve. Universities are encouraged to select the suitable undergraduate level at which to begin integrating BIM based on learner needs and proficiency, pedagogical considerations, and practical issues of university facilitation and capacities. However, it is preferable to initiate BIM at the undergraduate level rather than the postgraduate level, because students will strengthen their BIM knowledge and skills through projects and training under the supervision of academic tutors, building their experience with more support and facilitation

throughout their academic journeys. Thus, once students have completed this academic level, they will be ready to work on real projects without difficulty. Undoubtedly, integration of BIM at the postgraduate level is vital to advance the field of BIM research. In addition, it is recommended that the bachelor's degree should offer students appropriate knowledge and skills in BIM, including those of the BIM modeler and facilitator, BIM analyst, BIM manager, and BIM coordinator, which will result in graduate students who are BIM experts, and who "think BIM".

Table 3: BIM learnin	g outcomes at ι	undergraduate	architectural	education in the UK
	5			

"Level	Knowledge and understanding	Practical skills	Transferable skills
4	<ul> <li>BIM business</li> <li>Importance of BIM collaboration</li> </ul>	• Introduction to technology utilized in various disciplines	BIM as process/people/ technology/policy
5	<ul> <li>Supply chain</li> <li>The conception of BIM in construction operation</li> <li>Stakeholders' business drivers</li> </ul>	<ul> <li>BIM system attributes</li> <li>BIM applications and tools</li> <li>Using visual representation</li> </ul>	<ul> <li>Collective working.</li> <li>Communication multidisciplinary teams.</li> <li>Software is the service platform for projects</li> <li>Sustainability, lifecycle and Value</li> </ul>
6	<ul> <li>Contractual and legal framework / People/ management/regulation</li> <li>BIM across disciplines</li> </ul>	Technical knowledge: • Sustainability. • Materials and Structures.	<ul> <li>Management/ Procedure:</li> <li>BIM protocols.</li> <li>Data flows and Information</li> <li>How to deliver projects by applying BIM."</li> </ul>

# 10 Proposed BIM-integrated curriculum for architectural education in Libya

This section presents a suggested framework for the development of a BIM-integrated curriculum, in which students are assigned BIM-related courses according to their year of study. A framework for introducing BIM into certified architectural engineering courses is developed to serve as a guide for shaping and approving BIM adoption and assisting architectural educators in moving forward confidently and swiftly. The basic principle of BIM is to integrate many components that need to be integrated; additionally, a sequential learning procedure must be provided through BIM integration, which needs a variety of المؤتمر الوطني الثاني **لتطوير مؤسسات التعليم العالي في ليبيا** The Second National Conference For Developing Higher Education Institutions In Libya جامعة بني وليد وعبر تقنية zoom بتاريخ 2021/10/07



interactions between various distinct domains to occur in multiple fields. It is critical to recognize that a BIM learning framework affects the architectural curriculum, BIM software programs, and BIM learners. The central aim is to develop a BIM-integrated curriculum for four academic years of architectural education by altering or adding themes to the curriculum that cover the following topics:

- Fundamental notions and knowledge of BIM technologies and processes.
- Application areas in varying construction procedures (such as constructability review, clash detection, communication, visualization and simulation).
- BIM standards and BIM execution planning.
- BIM-based construction project management skills.
- Expandability to other ICT related to architectural and construction practices.
- Software compatibility.

This research aims to develop a BIM-integrated curriculum for architectural education in Libya. Libya's undergraduate architectural program comprises five years: one foundation year, and four academic years. BIM integration is recommended to begin in the first academic year. Before the distribution of the BIM learning framework, it is important to first define what the foundation year entails in Libyan engineering education.

### 10.1 Foundation year

Students initially join university faculties of engineering for a foundation year before specializing in their major. The foundation year is divided into two semesters, each of which has a variety of courses. All subjects taught during this year are general, offering only basic science knowledge, and students are required to have grasped these subjects before being allowed to choose a major. These courses include Physics 1 and 2, Mathematics 1 and 2, Chemistry, and theoretical courses including Human Needs, English, Introduction to Technical Drawing, Computer Science, and Properties Materials. Following this year, a specialized stage is introduced called Architecture, Civil Engineering, Mechanics, and Communications. Transfer to this stage is contingent upon student performance and rating during the foundation year, and students who wish to attend the Architectural Department may be required to pass tests in drawing and imagination.

By understanding the type of the foundation year an important question arises: is it possible to include BIM education in this year? It looks that it is not an easy process, because this is a general year with common subjects for all university departments, and it is not possible to remove or modify some subjects, such as Materials courses, for the benefit of certain faculties. Nevertheless, these courses may benefit students indirectly, as students can gain knowledge about the properties of the materials they utilize in design and construction during some themes which can be one of a BIM assignment. These skills and knowledge can be beneficial at the application stage when students begin creating simulations and employing BIM's cost tools.

On the other hand, the Technical Drawing course serves as an introduction to the fundamentals of architectural drawing. This course teaches students the fundamentals of technical drawing. This subject might be thought of as a warm-up for the first academic year's architectural drawing classes. Manual drawing teaches learners about the relationship between elements and helps them develop their imaginative abilities.

# 10.2 Four-Year BIM-Integrated Curriculum

The initial BIM inclusion in architectural education will be integrated into the undergraduate BIM framework, to build a BIM learning curve that encompasses both practical skills and conceptual knowledge in BIM. Thus, the first two academic years need to emphasize modeling, analysis, and developing individual skills, while the last two years should emphasize cooperation and complexity



throughout the collaboration, including a crossdisciplinary project in teamwork [33], [44], [45]. This section describes the distribution of BIM learning objectives and expected outcomes throughout the academic years of the undergraduate architectural program (see Table 2), based on the reviewed literature.

Table 4:	BIM Learnina	obiectives an	d outcomes	for unde	eraraduate	architectural	education
TUDIC 4.	Divi Leaning	objectives un	u outcomes	joi unut	. gruuuute	urchitecturur	cuucution

Year	Learning objectives	Learning outcomes
Year 1: An introduction to BIM	Basic BIM theoretical background knowledge	<ul> <li>Define typical BIM terminology.</li> <li>Recognize the benefits of BIM.</li> <li>Understanding of BIM technology and modelling process.</li> </ul>
Year 2: BIM technology theory and initial practice	<ul><li>BIM conceptual knowledge</li><li>BIM practical skills</li><li>BIM tools of 2D and 3D</li></ul>	<ul> <li>Recognize the theoretical and practical characteristics of non-BIM and BIM models.</li> <li>Begin by utilizing the primary tools for 2D sketching and 3D creation.</li> <li>Create a basic render for a single project on 2D and 3D models</li> </ul>
Year 3: BIM application	<ul><li> 4D BIM modelling tool</li><li> 5D BIM modelling tool</li><li> BIM and parametric design</li></ul>	<ul> <li>Use a 4D and 5D BIM model in a small project.</li> <li>Understanding of parametric design by using BIM tools.</li> <li>Recognize the roles and responsibilities of participants in a typical BIM-based project.</li> </ul>
Year 4: BIM mastery	<ul> <li>6D and 7D BIM modelling tools</li> <li>Sharing and management project</li> <li>Collaboration with other specialists</li> </ul>	<ul> <li>Use a 6D and 7D BIM model in a project</li> <li>Communication in multidisciplinary teams.</li> <li>Interact with others and be able to work cooperatively within a team.</li> <li>Provide engineering and design solutions via the use of BIM tools.</li> <li>Develop, visualize, amend, evaluate, process, and manage data associated with BIM models</li> </ul>

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• Gain an understanding of the modeling process.

#### **10.2.2 Year 2: BIM technology theory and initial practice**

Once students have learned the conceptual paradigm of BIM, they are prepared to go to the second year of architecture programs. A few practical applications of 2D and 3D BIM must be mastered by students in the second year in order to have a holistic understanding of BIM. The second-year can be devoted entirely to developing conceptual knowledge and practical skills in BIM, with students evaluating their design analyses and exercises. Such exercises can hone their thoughts, and students can be able to successfully exceed others. This phase can be divided into theoretical and practical knowledge, both of which can be acquired in standalone courses. Moreover, the program should include concepts of environmental design that can assist students in their usage of simulation tools included with BIM software this year.

This year's teaching program may include a design studio, where students can create and present complete small projects through the use of 3D BIM modelling tools and materials [43]. Architectural students should produce a simple render for a project at the culmination of the second year. In general, by the end of their second year of architectural education, students should be able to:

- Recognize the theoretical and practical characteristics of non-BIM and BIM models.
- Begin by utilizing the primary tools for 2D sketching and 3D creation.
- Construct a whole small project using BIM modeling tools and materials.
- Create a basic render for a single project on 2D and 3D models.

#### **10.2.3 Year 3: BIM application**

The third year of architectural education challenges students' design capabilities and introduces them to using BIM in a fully-fledged way. For many, this is the most critical year, which determines their

#### **10.2.1 Year 1: An introduction to BIM**

The first year of every engineering educational program is critical, including in architectural studies. Students must study the construction lifespan and comprehend and train on design concepts and architectural theory, mainly using manual techniques. This expertise and ability will be reflected in the quality of their later BIM modeling capabilities.

It is very important to understand that BIM is not a design tool; it is a tool for intelligent modeling. Because the quality of a product is determined by user skills, it is important to develop the architectural skillset prior to beginning to use any computer tool. Students are not required to learn how to use a CAD system or any other computer tool, as this may have a detrimental influence on their ability to use BIM technology [27]. When students become accustomed to the CAD system and assume that the BIM system is the same, it takes more effort to bridge the transition between the CAD and BIM paradigms. The procedure becomes more complex when mistakes and conflicts occur. Furthermore, applying computer technologies at this year may suffocate students' creative abilities in the design phase and inspiration.

Students need to master architectural sketching fundamentals such as diminutions and building components. They ought to be able to draw these interactions between details and building components manually. Students begin to acquire knowledge of material names and qualities at this year, as well as an understanding of how technology affects the architectural profession and projects. Additionally, the stage entails a theoretical background to BIM technology, followed by a discussion of the value of BIM software with examples. By the end of their first year of architectural education, students should be able to:

- Comprehend and master the principles and theories of architecture.
- Define typical BIM terminology.
- Recognize the benefits of BIM.



## 10.2.4 Year 4: BIM mastery (process, technology, integration, and collaboration)

The fourth and final year of architectural education is the most critical notion in BIM, since it requires students to practice and use all BIM processes and technologies in a whole project. This year's educational curriculum can be split into four stages.

**First stage:** Students must understand the notion of file sharing and management amongst architects working in a team. Students learn how to use BIM to collaborate on designs, which enhances the quality of projects. This stage denotes interdisciplinary collaboration on a single project (for example, civil engineering and mechanical). Students are taught and practice working together in multidisciplinary teams.

**Second stage:** Students need to learn BIM through exchanging data and tools with other project professionals. They should be able to work with coordination and management technologies to minimize conflict in a project. Students gain skills in resolving disagreements between disciplines, communicating concerns, comprehending contracts, and associating a model with its data.

**Third stage:** Students must be capable of creating all project tables and documents as well as calculating the costs of the project BIM software. They should be able to predict the duration of the building process through the use of working drawing studios.

**Fourth stage:** This stage entails collaboration amongst multidisciplinary teams of architects on a single large-scale project (with colleagues such as civil engineers and mechanical and electrical engineers). It involves a comprehensive application of all BIM courses taught during the academic curriculum. It is required to do this application in real-world projects with real-world contractors, under university supervision. The educators must immediate post-graduation plans. As described in the preceding theoretical analysis, BIM is a multidimensional technology that possesses wide ranging capabilities in and of itself. Students in this year must begin to grasp 4D and 5D notions and principles of BIM through standalone courses [47]. They should be proficient in the use of simulation and coordination tools, as well as simulation programs such as Autodesk Ecotect Analysis. Additionally, this year includes an introduction to parametric design through BIM technology.

Architectural students need to understand the theoretical simulation in 4D method, which can be taught in BIM standalone courses, and be able to apply their knowledge in small projects utilizing a solar design. Furthermore, students must be able to envision the impact on design. This year, students receive instruction in applying the 5D notion to the project's components. They should be aware of BIM impact on the cost and quality of the project and its materials. In this year, students should undertake teamwork on a single project, and develop the ability to coordinate their work in a centralized file.

By the end of this year, students should have completed a comprehensive project applying 2D, 3D, 4D, and 5D BIM tools into a single application that incorporates all prior learning. Students also learn how can generate complete functional drawings with all necessary information and documentation requirements for the project by utilizing BIM tools while working in a design studio (medium-scale projects like plans, sections, elevations, air-condition ducts, firefighting pipes and electrical connections). By the end of the third year, architectural students should be able to:

- Use BIM tools to gain a better understanding of parametric design.
- Use a 4D and 5D BIM model in a small project.
- Recognize the BIM process and its application in a real-world project.
- Recognize the roles and responsibilities of participants in a typical BIM-based project.
- Use BIM tools, and create detailed working drawings and documentation for projects.



renovation of existing architectural education programs can place students in a strong learning position related to advanced digital technologies.

BIM education is a facilitation process for students to gain skills and competence associated with BIM technology. Therefore, architectural students can be able to work in any multinational organization that uses BIM technology, allowing them to become international architects. As a result, it is possible to conclude that a curriculum framework for integrating BIM can help fortify architectural programs in Libya, and increase the quality and readiness of architecture graduates, and to meet construction industry needs.

### 11.1 Limitations

The study is limited to BIM integrated curriculum for undergraduate architectural education in Libya. There are other limitations such as the study focus on BIM curriculum only without any consideration on the institutional strategic plan that supports BIM education integration into higher education. In addition, the study faces a lack of adequate literature review that discuss BIM competencies needed for architectural students.

### 11.2 Further research

Considering the limitation of this research, there is a need for further research in order to support the higher education institution's ability to develop a strategic plan such that they may adopt and put in place BIM as a core course in architectural programs.

In addition, there is a need for more research that focuses on establishing a BIM body of knowledge in order to cover the shortage of systematic understanding and an absence of establishing basic knowledge, skills, and capabilities to successfully deploy BIM within the architectural program to meet the needs of architectural students and the construction industry. ensure that students are adequately prepared to work on real-world projects following graduation.

By the end of their fourth year of architectural education, students should be able to:

- Gain an understanding of how BIM is used to facilitate communication and cooperation.
- Interact with others and be able to work cooperatively within a team.
- Gain an understanding of the process of data communication using BIM models.
- Provide engineering and design solutions via the use of BIM tools.
- Execute projects with BIM.
- Develop, visualize, amend, evaluate, process, and manage data associated with BIM models.

It is also recommended that the legal aspects of BIM be introduced to students, to gain a better understanding of how the BIM model functions in a completely integrated project. This will enable students to evaluate BIM within the context of contract terminology and discover best practices for incorporating BIM into project contracts, while also offering an in-depth understanding of intellectual property rights, insurance, and risk allocation. Students will have an awareness of BIM's history and procedures as a result of this legal knowledge [46].

# 11 Conclusion

This paper aims at the development of BIMintegrated curriculum framework for undergraduate architectural education in Libya. To achieve this aim, a research methodology was developed consisting of systematic literature review. A significant а discussion has taken place as a result of reviewing international publications related to BIM education development. BIM education in Libya remains at a very primitive level in the light of industry demands and technical requirements compared with advanced BIM in other countries. The proposed BIM-integrated curriculum was developed for undergraduate architectural education along with the yearly modulation of subjects taught at the undergraduate architectural education and related disciplines. The



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