Incorporating BIM into the Academic Curricula of Faculties of Architecture within the Framework of Standards for Engineering Education

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Abstract

Governments and the architectural, engineering, and construction industry (AEC) around the world have paid great attention to the application of Building Information Modeling in their projects due to the many advantages it offers, which called on educational institutions to include BIM in their curricula and to qualify new graduates with the competencies and expertise necessary to keep pace with development and to supply the cadres of AEC companies.This research presents educational frameworks and current approaches to integrating BIM into educational curricula around the world, and critical success factors for integrating BIM into education. In this research, an educational BIM framework was proposed based on the research and studies presented in the BIM and Education field and a detailed work plan based on engineering standards (ABET – NARS) for the BIM integrating process in the Faculty of Architecture - Damascus University. The work plan was based on a gradual transition for BIM integration, starting from the first year to the fifth year within three levels.The proposed framework was verified by the academics at the Faculty of Architecture - Damascus University through conducting qualitative interviews to evaluate and improve the framework Comments were taken into account when developing the final proposal. At the end of the research, many recommendations and future directions were presented.

Keywords: Building Information Modeling, BIM; Architectural Design; Education; Curriculum Design; Standards; Framework; BIM Processes; BIM Technologies; Integration.

1. Introduction

The digital age has changed the working environment in the AEC industry on how buildings can be designated, documented, and constructed in a smarter way than before through the use of Building Information Modeling (BIM) that has revolutionized the traditional practice of the construction industry worldwide as BIM is taking an upward trend, therefor the AEC managers are increasingly looking forward to developing their projects and their operational management through the application of BIM as the BIM process creates information models and associated information which has used throughout the life cycle of building/infrastructure facilities or assets. [1]

and to keep up with this development and achieve the desired benefits of BIM application in the AEC industry world, universities around the world are making concerted efforts to include BIM in their educational curricula by developing the required pedagogical platforms and approaches to embed BIM in their way and became a cornerstone of it.

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This rapid development of information technology requires a new approach based on international standards, especially in architecture and which is characterized by innovation and greatly influenced by technological progress.

Because of this, the importance of the virtual world of BIM in education emerges as a promising technological approach to constructive and productive education, and the application of BIM within the curricula of educational institutions has become a top priority, especially in countries where BIM is currently have adopted, so that future professionals can compete in the BIM methodology, as engineering graduates today need to cooperate Strong interdisciplinary and teamwork skills that contribute to solving complex problems that require multidisciplinary solutions, in addition to knowledge of sciences of interest to their profession such as social, environmental and economic and how to apply basic engineering sciences and technical skills in practical applications.

Nowadays, many countries are in different stages of implementing and adopting BIM in their legislation. Researchers and practitioners have made many efforts to set standards for BIM implementation. [2]

In light of this development, BIM has become an academic reality. Therefore, significant steps must have taken toward integrating BIM into educational institutions in the Syrian Arab Republic. This research presents the current strategies adopted for teaching BIM in academic institutions around the world and a proposed engineering standards-based model(ABET - NARS) for integrating BIM within the faculties of architecture in Syria through a case study - Faculty of Architectural Engineering - Damascus University, after reviewing, studying and analyzing research and literature within the field of BIM and Education, in addition to evaluating the proposal by the academics in the studying unit, analyzing the results, and presenting recommendations and future directions.

2. Research Background

[3] The article presented a model for integrating BIM into the curricula of faculties of architecture based on gradual levels starting from the beginner level to a transitional level in the second academic year and then the advanced level in the third academic year. Each level determined four aspects: the content, how to teach BIM, the teaching and learning environment, and the Learning outcomes and desired skill sets,

- Beginner level or First Year: Emphasis placed on individual modeling skills.
- Transitional level or Second Year: Emphasis placed on collaborative skills and teamwork as part of an integrated team.
- Third Year or third level: Collaborative skills enhanced in collaboration with companies within their architectural design projects.

[4] This paper examines the current methods of integrating BIM within the educational programs offered by 25 leading international universities in the field of engineering according to the Times Higher University (2012) classification, and due to the lack of a national educational framework that includes BIM in New Zealand The work has done to create a draft BIM framework for the higher education sector which seeks to integrate disciplines across the traditional scope, acknowledges BIM critical success factors, is informed by overseas programs and focused on learning outcomes. The research also aimed to make a consensus between academic institutions and industry.

[5] This research examines a collaborative BIM educational framework developed by a joint national industry/academic initiative in Australia in 2011-2012, including a conceptual workflow and identifying, classifying, and aggregating BIM competency elements into a BIM competency knowledge base for use in developing BIM education. The foundation is a shared understanding of BIM deliverables and requirements. As well As. the support for national efforts to enhance BIM learning. The BIM framework included six components: a- identifying BIM competencies B- classifying BIM competencies C- developing BIM learning modules D- developing an industry framework for professional development E- developing or adopting an academic framework F- establishing a BIM institute, the first three components addressed in this research, and future research will focus on developing educational BIM materials and creating a customized organizational structure.

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[6] This research included a proposal for a strategic approach to include BIM in university programs for architecture colleges in the Kingdom of Saudi Arabia. Depending on the methods of collecting quantitative and qualitative data and conducting a critical review of the strategies and attempts used to include BIM in architectural programs, know the level of the BIM application in the AEC industry and identify educational obstacles and gaps to include BIM. The research validated the proposed framework by exploring the opinions of academics in the Department of Architecture.
The Initial framework to embed BIM within Undergraduate Architecture Programmes in KSA suggests that the BIM learning curve should be embedded from the first year with the concept of Non-BIM 2D & 3D modeling, the second year: Technology, the third year: Process, then the fourth and five years with Integrated Design.

[7] This research is considered one of the most remarkable research related to the design of the BIM curricula in AEC education, through which more than 375 studies have been analyzed.
The research aims to highlight the directions and gaps in BIM education, conduct a systematic review of research on the design of BIM curricula in AEC education, and provide a set of educational strategies implemented that address a variety of important pedagogical issues such as enrolment of students, optional or required BIM use, important competencies and skills, tutoring methods, industry engagement, designing assignments, and assessment methods and criteria with detailed discussions on their effects and effectiveness through various studies and contexts to develop BIM educational curriculum design framework.

[8] The researcher conducted an analytical study to measure the extent of the application of BIM technology thinking in the list of the Department of Architecture at the Faculty of Engineering, Mansoura University in Egypt, and divided the materials into four groups:

- First group: fully modified to be introductory courses during which the student learns the basics of BIM.
- Second group: courses developed in part using BIM.
- Third group: courses developed entirely using BIM.
- Fourth group: includes courses that are not related to BIM technology.

[9] This research aims to conduct a preliminary study to develop an implementation framework for introducing BIM based on Autodesk programs in the construction courses of the Department of Architectural Engineering at the United Arab Emirates University. This study was conducted on the academic performance of students and their degree of motivation and satisfaction by using the questionnaire method and the method of comparisons of training and academic degrees for students in addition to the evaluation of teachers, and through this, the problems of including BIM were identified and solutions were found. The study will expand to other universities in the future and the conclusions used to create a framework guide for integrating BIM into the AEC curriculum.

[10] The researchers proposed a framework consisting of three main aspects:

- Skills to be acquired: Level of education- Core competencies- BIM-specific knowledge
- Teaching approach: Teaching methods- Evaluation methods- Technological environment
- Implementation approach: Approach- Timing- Industrial partnerships

In addition, this article presented a case study from a Canadian engineering school to evaluate and validate the proposed framework and to illustrate the challenges. The positive aspect of ETS-Montreal is the interdisciplinary nature of BIM education content. The experience also highlighted that industry involvement is reflected in the selection of skilled professionals as educators and the definition of training content. This research indicates that the undergraduate degree level is where core engineering competencies are expected to be acquired. However, the framework moved away from the university administrations' participation in the change process.

[11] This study has conducted at KSUAE University in Kazan - Russia - as part of a second-year undergraduate course during which students present four projects - two in each fall and spring semester - intending to develop a comprehensive methodology for effective teaching in the Architectural Environment Design course with extensive use of BIM techniques and digital

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modeling, For more than three years and has given stable and good results. The study covers four study projects:

- Compositional Structuring of Architectural Forms
- Architectural facade design
- Interior design
- Exterior design

This methodology is characterized by

- Achieve the architectural concept within the current technologies framework.
- The number of required tasks increased gradually.
- Apply algorithmic design methods (Grasshopper) to build solid structures, lattices, and structural bars.
- Find more effective design solutions.
- Develop a technique to define the geometric parameters of structural elements in the form of tables in Revit Architecture to build complex architectural forms.
- The sequence of stages is also the basis for the formation of a comprehensive understanding of the fundamentals of architectural design within the framework of the undergraduate program at DAS.
- Explore how a single architectural topic succeeds in teaching 3D modeling.

[12] This article relies on the analysis of the methods and protocols used by academic institutions around the world to integrate BIM applications into AEC colleges and to determine a set of organizational guidelines that are a more common basis for these institutions to raise the level of integration by conducting a literature review of studies on Wos and Scopus through Prisma in the period from 2016 To 2020, where 23 articles were studied and analyzed. The results showed the need to develop unified academic guidelines for universities to develop a strategy for curriculum modifications and teaching methods.

As a result of reviewing previous studies on teaching BIM, it was concluded that:

- Each country and university develop the BIM education process individually without a common framework or procedure.
- BIM embedding process differs between universities within the curricula content, duration, and teaching method.
- It is necessary to embed BIM into the curricula and distinguish them with a cooperative approach.
- BIM education in universities is often limited to program training in isolated courses.
- Through the analyses of the studies, there is no specification of the educational programs' content or an elaboration detailing the strategies presented.
- In architectural education, it is necessary to concentrate on increasing students' interest in analysis and simulation.
- Many studies agree that students should work similarly to real-life conditions, where students of architectural, structural, mechanical, and electrical programs collaborate to work on a shared project.
- Also, many studies have shown the impact of digital tools on the application of BIM in the education process and the possibility of integrating it into architecture education.
- To fully profit from BIM embedding into education, multiple disciplines must be addressed within the curricula to understand the BIM integration capabilities throughout the project life cycle.
- Enhancing the academic curriculum, lectures, seminars, and workshops must be continuous.
- It is necessary to focus on the importance of continuing to learn manual skills, especially in the first university stages.

It was concluded that there is an urgent need to integrate BIM into AEC universities through a well-studied and integrated framework that considers the need for integration and cooperation between disciplines. Therefore, the research aims to propose a framework for integrating BIM in the Faculty of Architecture - Damascus University, Syria, focusing on the cooperation between disciplines and based on the international reference standards for engineering education (ABET).

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The application of standards helps to reach the general goals of education, to obtain real quality, and to achieve excellence.

3. Importance of BIM

The traditional systems deal with each project phase and its teams separately, the main feature of BIM is the integration of the different project phases (project management life cycle) and its teams [13]. BIM proves its capability to enhance the cooperation between all project parties [14] where BIM is deemed as an environment that effectively combines all liabilities and endeavors from all project stakeholders through diverse project phases to deliver a functional sophisticated and innovative product replying to all parties and project objectives [15] [16]. Using BIM with partnering agreements reduces disputes, eliminates conflict of interest, and allows sharing of knowledge, healthy interaction between project stakeholders, and improving problem-solving techniques [17]. Also, through BIM, develop a BIM-based stakeholder information exchange (IE) workflow scheme during the planning phase in smart construction megaprojects (SCMPs) that faces a massive IE challenge [18]. Benefits of BIM and Digital Engineering (DE) include the ability to create 3D models that improve analysis of geotechnical elements, improve visualization, help resolve conflicts and issues, and enable the development of virtual and augmented reality (VR/AR) solutions [1]. BIM can be applied to several topics. Using BIM in the transportation industry through real way construction projects [19]. Furthermore, BIM technology can be applied to achieve sustainability and improve the energy efficiency and the life cycle of the building through the application of the skylight system and the Trombe wall as a passive design strategy [20] [21]. The importance of using BIM technology in studying the lighting performance in buildings to develop the best design solutions and upgrade to obtain optimal performance, whether in the design stage or the evaluation stage of an existing building through the use of environmental analysis programs such as Ecotect- Desktop Radiance [22]. BIM implementation in the AEC industry projects leads to improving the project's performance and efficiency and not only solving the massive AEC project's problems and reaping the benefits of its implementation [23] where BIM contributes to resolving conflicts and delays that exist due to a lack of interoperability [24]. The focus of the construction industry now is to eliminate waste and inefficiency to improve quality and profitability [15] [16]. BIM can also be used to manage risks in AEC industry projects where the management system reviews the conventional risk assessment procedures, and introduce developed criteria and become an everyday practice of all construction projects [25]. The field of heritage is also considered one of the most important areas affected by the application of BIM, where a clear and detailed strategy was developed to implement Building Information Modeling (BIM) [26], and applied as an effective method to protect, preserve and maintain Syrian heritage so that it is integrated with the heritage risk management plan [27]. It can also be applied in the field of studying nanofibers where one of the integrations between BIM and nanofibers investigates a positive relationship between the needle diameter and the diameter of the electrospun PVDF nanofibers [28]. However, the adoption level of BIM remains much lower than expected [29]. Syrian educational bodies need to allocate more time and effort to qualify engineers and help them keep up to date with the latest technologies [30]. The most significant barriers against BIM adoption are lack of expertise, standardization, and protocols. And, most influential drivers as the Availability of trained professionals to handle the tools, Proof of cost savings by its adoption, BIM Software affordability, and awareness of the technology among the industry stakeholders [31].

4. v

BIM creates a paradigm shift in architecture and changes the design methods used in the latest architectural applications and ways of preparing architectural documents. The American Association of Architects (AIA), in its Integrated Application for Integrative Education report, defines Building Information Modeling (BIM) as "a catalyst for rethinking architectural education" [32]

Incorporating BIM into architectural curricula is a promising way to integrate advanced digital technologies into architectural education while preserving basic design skills that will remain an essential base. The importance of integrating BIM within education also comes in reducing the gap between education and the AEC industry by linking theoretical education with practical application

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[33]. While the adoption of new ideas requires a framework for proper implementation and use, and the clarity of the framework structure leads to a better understanding of the technology [34]

Many technical challenges can face in the application of BIM, which depends on integrated collaborative work between all disciplines, and these challenges may be cultural and educational. Also, BIM has been considered a threat to creativity in many architectural approaches where BIM does not support design innovation and is more suited to supporting building fabrication than architecture design, which may be inaccurate.

The debate about the applicability of BIM in the early design stages is still ongoing. However, some define BIM as a process that brings performance information and environmental conditions to simulate the design, allowing unprecedented improvements to the design process. There can also be obstacles to BIM integration due to inflexible or narrow curricula that cannot afford elective courses; There can be limitations due to graduation requirements and even a lack of reference materials for teaching [35] and the existing studies and research indicate that the offering of BIM courses at the undergraduate level is relatively small compared to the offering of these courses in the majority of programs at the postgraduate level.

Mitigate these challenges and adopting BIM requires changes in the organizational culture and calls for new roles and skills for participants [36] and the way towards adopting BIM is related to the concept of readiness at the organizational level as indicated in the theory of organizational readiness for change. [37].

5. BIM & Educational Standards

BAF Forums:

BAF has developed a framework with a set of BIM learning outcomes that must update within UK universities, and the BAF framework is flexible in adopting BIM. It has been suggested that each university seeking to integrate BIM should do according to its style and method, depending on several factors and not necessarily following the latest ways. The UK School of Architecture has based its undergraduate program on three levels to achieve learning outcomes in three main areas: understanding & knowledge, practical skills, and transferable skills. [38].

Table 1: BIM ACADEMIC FORUM LEARNING OUTCOMES

	4	5	6
Knowledge & Understanding	• Importance of collaboration • The business of BIM.	• BIM concepts – construction processes. • Stakeholders' business drivers. • Supply chain integration.	• BIM across the disciplines. • Contractual and legal frameworks/regulation. • People/change management
Practical Skills	• Introduction to technology used across disciplines	• Use of visual representations. • BIM tools and applications. • Attributes of a BIM system.	• Technical know-how. • Structures and materials. • Sustainability.
Transferable Skills	• BIM as a process/ technology/people/policy.	• Value, lifecycle and sustainability. 'Software-as-a-service' platforms for projects. • Collaborative working. • Communication within interdisciplinary teams.	• Process/management. • How to deliver projects using BIM. • Information and data flows. • BIM protocols/EIR

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IMAC Framework:

[39] proposed an "IMAC" framework for BIM collaborative education consisting of four main phases that can consider as a basis for learning (Illustration, Manipulation, Application, and Collaboration). The framework aims to help BIM educators measure their curricula to improve collaborative design within AEC -ES. The work stages correspond to the achievement levels defined in the use of BIM models. It can be applied effectively to map BIM/ stages of maturity of collaborative education across educational curricula and to set goals for future development. He also developed a mapping exercise for current courses in Australian universities, focusing on building technology, environment, management, information technology, and specialist aspects.

I. Illustration Phase: An introductory phase in which the concept of BIM is used for AEC students to illustrate key concepts in their disciplines as each department uses a well-developed BIM model to explore the building.
II. Manipulation Phase: In this phase, the students interact with existing models, make some changes in the BIM model, and, or create base elements and seek to develop student skills in IT and teamwork.
III. Application phase: Students solve problems related to the major by applying the basic theoretical knowledge they have acquired until now. Students are also informed about the importance of engineering and sustainability; and how they can work and share data with other disciplines.
IV. Collaboration Phase: Students from different disciplines work together on a shared project, which contributes to bridging the gap between AEC departments. Also, teaching students the different types of contracts between team members.

The stages mapped into different levels in the Taxonomy of Learning proposed by (Bloom et al.) and expanded upon by (Krathwohl et al.) An IMAC framework intended to help develop the two; technical skills (information technology and subject-specific skills) and soft skills (collaboration and teamwork). It extends to two domains: The Effective domain & Cognitive domain.

ADDIE Model:

The ADDIE model is considered one of the most significant instructional design models. It provides a structured framework for creating an integrated and effective educational curriculum. The ADDIE model comprises five phases: Analysis- Design- Develop- Implementation- Evaluation.

NARS Standard: [40] [41]

For the academic sector, NARS standards include the following foundation normative components:

- Knowledge and Understanding: Includes a set of academic knowledge and concepts that the graduate must acquire at the end of his studies.
- Intellectual Abilities: Expresses the total mental capabilities expected to be acquired by the graduate, such as the ability to analyze, discuss and draw conclusions, the ability to present problems and find solutions to them, and the ability to innovate.
- Practical and Professional Skills: The ability to convert acquired theoretical knowledge into practical applications.
- General Transferable Skills: General skills unrelated to the specialization, such as numeracy skills, communication skills, management skills, and teamwork skills.

ABET Standard: [42]

A. An ability to apply knowledge of mathematics, science, and engineering.
B. An ability to design and conduct experiments, as well as to analyze and interpret data.
C. An ability to design a system, component, or process to meet desired needs.
D. An ability to function on multi-disciplinary teams.
E. An ability to identify, formulate, and solve engineering problems.
F. An understanding of professional and ethical responsibility.
G. An ability to communicate effectively.
H. The broad education necessary to understand the impact of engineering solutions in a global and societal context.

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I. A recognition of the need for, and an ability to engage in life-long learning.
J. A knowledge of contemporary issues.
K. An Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

UIA AND ARCHITECTURAL EDUCATION:

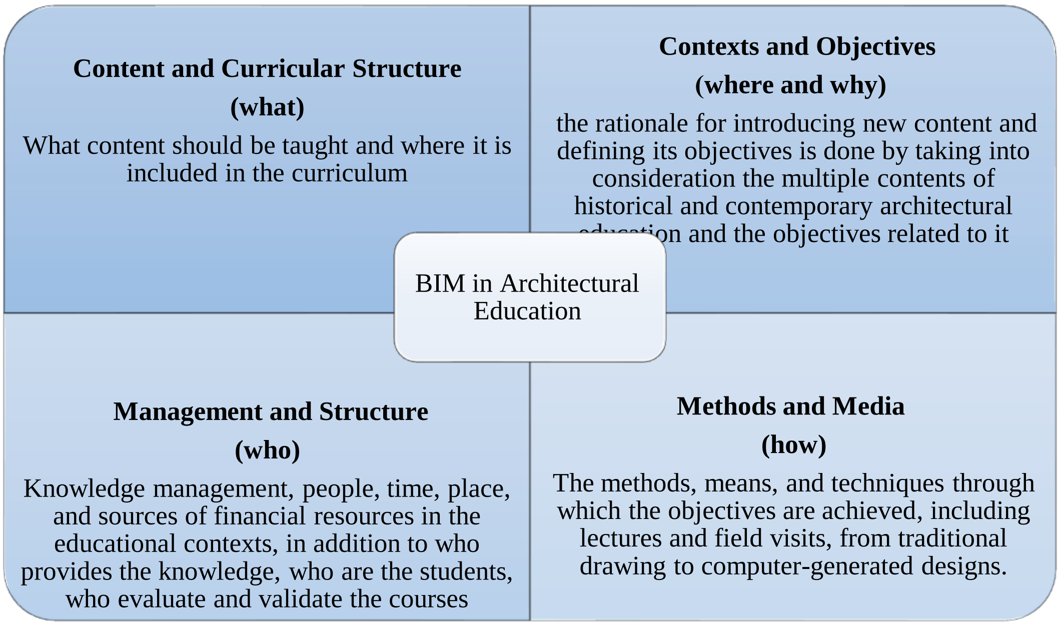

Figure 1: Architectural Education: Basic Categories and Dimensions [43]

6. Research Methodology:

For completing this research, an educational BIM framework and detailed plan for the academic years have been developed after collecting data based on previous studies and research in the BIM and education field and analyzing the previous frameworks. The development of the framework is based on the internal regulations of the studied unit and verifying the proposal by conducting interviews with the administrative and teaching staff within the Faculty of Architecture - Damascus University and reaching the final proposal.

7. Discussions and Results:

The proposed framework for adopting BIM within education:

The researcher proposed to integrate BIM into the undergraduate program of the Faculty of Architecture - Damascus University according to the internal regulations of the bachelor's degree and the goals of the university according to standards, starting from the first year and gradually according to three levels over the five years. Students acquire skills covering various BIM core competencies: techniques, processes, and policies within a particular interest in collaboration with AEC industry organizations at the advanced level.

The implementation process is by distributing the courses into three groups:

- Courses developed entirely with BIM technology.
- Courses developed partially with BIM technology.
- Courses which not modified with BIM technology.

As for the teaching methods, they follow the main teaching methods approved by the university and faculty members, in addition to Project-Based Learning (PBL), which is an educational model based on learning “knowledge” and acquiring the necessary skills to deal with problem-solving and developing them by involving students in design and problem-solving, decision-making or verification activities and is also an appropriate opportunity for students to work relatively

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independently over long periods; It culminates in realistic products and presentations, which distinguishes it from the traditional teaching model.

The university will provide the structure that supports the teaching process through the academic curriculum and will coordinate with AEC companies to provide professional training opportunities for students and emphasize the importance of self-learning through research and the Internet, which contributes to meeting the growing educational needs.

The BIM teaching process will be done by introducing various BIM theories to university professors, appointing assistant BIM technicians at the college, training students by academics accredited by the university, or training professors by BIM experts appointed by the university. The educational content will be; presented through theoretical and practical lectures. The classrooms will be equipped with computers and equipping them with appropriate BIM technologies and software such as (Revit, Archicad, Ecotect, Navisworks, and Primavera ..), developing modeling skills, conducting seminars and workshops regularly, and benefiting from YouTube videos provided by Autodesk, BIM experts or from presentations show by BIM software instructors in addition to the necessity of Site visits to construction sites.

Throughout the courses, students gain knowledge and competencies that will be evaluated using two evaluation methods: formative and summative, by following the internal regulations for the bachelor's degree in the Faculty of Architecture at the University of Damascus. The formative evaluation aims to improve the learning process by providing continuous feedback, and also it is used to motivate students and diagnose their strengths and weaknesses. This evaluation shall be used to derive final grades. The summative method aims to assess students learning and general competencies at the end of the learning unit by comparing them to a standard and focusing on the result. It also requires more time from students and lecturers and takes place outside the classroom. This type of assessment is designated to obtain a final score, to allow progression to further studies, or to predict success in future studies.

The university administration may also establish a digital educational library for the university as a completed content to the information presented through the series of lectures for use by students and faculty members who are involved in BIM education. It includes a variety of books, research, websites, and visual materials related to the field of architecture and BIM. In addition, the educational programs about BIM tools and content are constantly updated.

Adopt the ADDIE model to implement the educational BIM framework to achieve the successful and complete application of BIM in educational institutions.

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The general framework of the proposed vision:

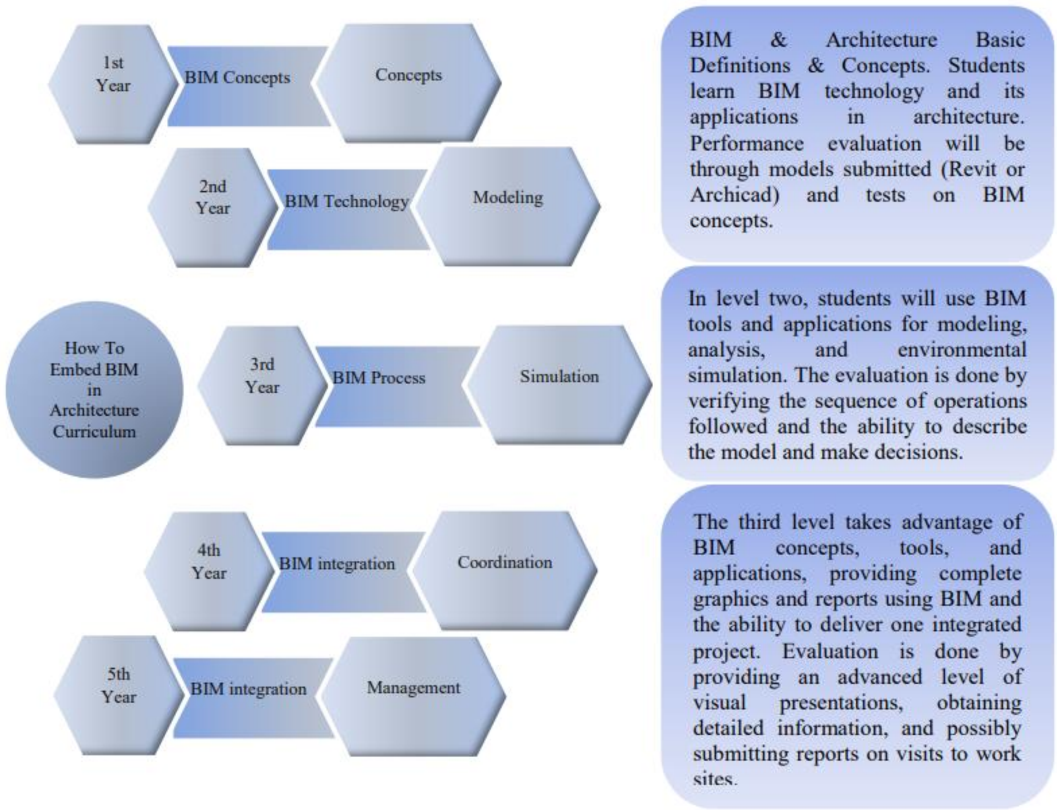

Figure 1: How to integrate BIM into the architectural academic curriculum

<u>First-year Work plan and the educational outcomes:</u>

Manual skills are preserved and developed, and BIM would be taught through a theoretical course.

- An introduction to BIM, the benefits of using it, and the difference between BIM, and traditional CAD programs
- Definition of the architect's role in the changing environment of the project.
- Present case studies in which BIM has been adopted with good educational outcomes.

Concept:

- Good knowledge of the principles and concepts of BIM and its various capabilities and applications in architecture.

Table 2: First-Year Courses

First Semester	Second Semester
Elements of Architecture and Basic of Architectural Design	Architectural Design1
Drawing and Visual Composition	Architectural Drawing and presentation
Mathematics, mechanics, and statics	Shadow and Perspective
Building Construction	Strength of Materials
History of the Architecture of Ancient Civilizations	Introduction to the Theory of Architecture
Foreign Language 1	Foreign Language 2
Arabic Language	Computer Driving❖

<u>Legend</u>	
(blue)	Courses developed partially with BIM technology.
(grey)	Courses not modified with BIM technology.

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Second-year work plan and the educational outcomes

The ability to modify an existing model and work on a small project.

Concept:

1. Understand how to apply any elements or information in the BIM model.
2. Understand the concept of parametric software.

Technology (Practical and Professional NARS Skills):

1. Students learn basic modeling skills using Revit or Archicad.
2. Selection of a component of the building and provide detailed information about it.
3. Design, presentation, and modeling of small architectural projects using BIM programs.

Table 3: Second-Year Courses

First Semester	Second Semester
Architectural Design 2	Architectural Design 2
Architectural proportions and formations	Architectural models
Structural Analysis	Theory of Construction
Building Materials	Building Finishing
Architectural Criticism	History of Architecture
Foreign Language 3	Foreign Language 4
National studies	Computer skills (Revit) ❖

Legend	
(blue)	Courses developed partially with BIM technology.
(grey)	Courses not modified with BIM technology.

Charts of tools, competencies, and educational outcomes for the 1st level according to ABET standards

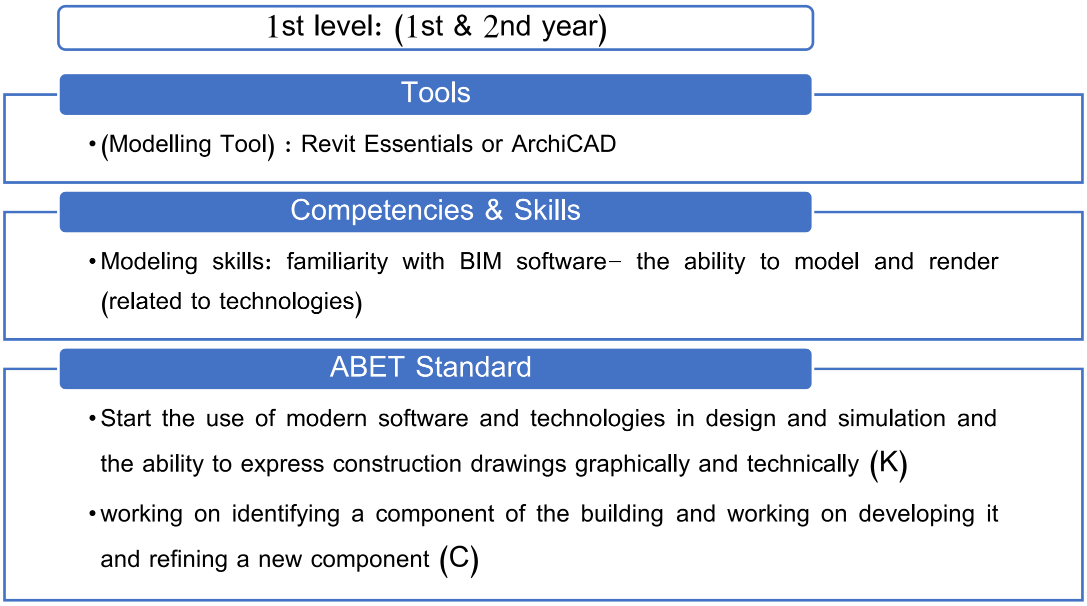

Figure 2: A chart of tools, competencies, and educational outcomes for the first level according to ABET standards

Third-year work plan and the educational outcomes:

Providing theoretical lectures within relevant academic subjects to present different case studies of similar projects that adopted the same approach and benefited from it.

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The application of digital BIM tools is also being expanded by:

- Application of using Revit in architectural design for presentation, modeling, and analysis purposes.
- Develop interior design learning using BIM through a 3D representation of interior spaces and furniture using REVIT.
- Explore the characteristics of families within BIM tools.
- Develop the skills of using environmental simulation and analysis tools such as Insight (Add-in For Revit) to analyze and simulate energy, wind, and lighting.
- Draw construction plans and represent them in two and three dimensions.
- Develop skills in using BIM applications by including MEP modeling courses.
- Knowledge and understanding of how HBIM technology can be applied in the rehabilitation of historic buildings.
- Read and manipulate data from the BIM information system.

Concept:

1. Understand the importance of building sustainability and the role of the BIM process and technology in achieving it.
2. Know and understand the role of BIM in reviving historic buildings.

Technology (Practical and Professional NARS Skills) :

1. The ability to collect, insert and extract data.
2. Using BIM as a capture tool to convert manual forms into digital and thus make adjustments more easily.
3. Explore interoperability issues between programs.

Process (Intellectual NARS Skills)

1. Enhance the dimension of sustainability in projects through design and develop a project based on the foundations of sustainability.
2. The process of analyzing energy, wind, and lighting to improve the project's performance.
3. The ability to make decisions regarding materials and lighting components' selection and methods display them.
4. Design and create models using BIM tools and platforms.

Table 4: Third-Year Courses

First Semester	Second Semester
Architectural Design 3 (Revit) ❖	Architectural Design 3 (Revit) ❖
Interior Design Revit+ Families Revit) ❖	Surveying and architectural documentation ❖(Revit)
History and Theory of City Planning	Landscape Architecture (Revit) ❖
Basic Execution drawings	Execution Designs for Traditional Buildings (Revit) ❖
Building Physics (Lighting, Sound, Insulation) (Revit+Insight) ❖	Building fixtures (sanitary, electrical, and mechanical (Modelling) (Revit MEP) ❖
Renovation of Historic Building and sites (Revit) ❖	History of Islamic Architecture

Legend	
(blue)	Courses developed partially with BIM technology.
(grey)	Courses not modified with BIM technology.

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Chart of tools, competencies, and educational outcomes for the second level according to ABET

During this stage, the real benefit of BIM programs is made

2nd level (3rd year)

Tools

- Modeling Tool: Revit Arch. Advanced – Revit Structure – Revit MEP (modeling)
- Energy Simulation Tools: Ecotect or Add-in software for Revit (Insight)

Competencies & Skills

- Modeling skills: design, rendering, analysis, and simulation (related to technologies).
- Practical efficiency through exchanging files within a single discipline (architecture) and extracting information.

ABET Standard

- Using modern software and technologies in design and simulation and the ability to express construction drawings graphically and technically (K)
- The ability to create vertical movement paths (stairs-elevators-electric stairs(C, E)
- on identifying a component of the building and working on developing it and refining a new component (C)
- The ability to choose and display building materials(C, E)
- The ability to conduct energy analysis of buildings and analyze data to improve the performance of the building(B)
- Learn the uses of ADD-in within Autodesk Revit .(I)
- Online self-learning as a complement to the educational content. (I)

Figure 3: A chart of tools, competencies, and educational outcomes for the second level according to ABET

Fourth-year work plan and the educational outcomes:

Throughout this year, theoretical lectures are presented to demonstrate the ability of BIM to coordinate between different disciplines, hold meetings, and achieve a collaborative work environment, in addition to better applying BIM digital tools through:

- Fully integrate BIM into the architectural design, visual representation of the project, and creation of all plans.
- Integrate BIM into construction designs.
- Implement the BIM system to produce detailed project designs and shop drawings.
- Learn how to work, link and coordinate between different engineering disciplines. In addition, to learning how to exchange BIM models.
- Use the BIM tools to extract information from the model.
- Analyse and manage data in a shared project.
- Simulate spatial data, model locations, building planning, and extract data from BIM systems such as (Autodesk Revit) to Geographic Information Systems (GIS) and vice versa.

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Concept:

1. Know the importance of collaborative design using BIM to improve the quality of projects.
2. A better understanding of building systems through using Revit in structural representation.
3. Students learn how to work with other disciplines using BIM tools and processes.

Technology (Practical and Professional NARS Skills):

1. Using Revit as the main program for submitting architectural design projects.
2. Share BIM models and files between different disciplines within the same team.
3. Coordinate all BIM drawings into a shared file and detect and resolve the conflicts in collaboration with the team.

Process (Intellectual NARS Skills):

1. How to work within a multidisciplinary team, define responsibilities within the team member, and work to detect and resolve conflicts.
2. Create one central file.

Integration & Collaboration (General Transferable Skills):

1. Share the model within the team.
2. Promote collaborative work and exchange information between different disciplines to qualify them and work better.
3. Integrate project delivery and coordinate between design and implementation in representing all details.

Table 5: Fourth-Year Courses

First Semester	Second Semester
Architectural Design 4 Revit (Shared Coordination + Clash Detection)❖	Architectural Design 4 Revit (Shared Coordination + Clash Detection) ❖
Urban planning and organization	Urban Planning Revit + GIS ❖
Environmental Science	Urban Sociology
Architectural Trends and Schools	History of Modern and contemporary architecture
Executive designs for high-rise building Revit Structure ❖	Executive designs for buildings with large spans Revit Structure ❖
Design and calculation of concrete structures Revit Structure ❖	Metal structural Design and calculate Revit Structure ❖

Legend	
(dark blue)	Courses developed entirely with BIM technology.
(light blue)	Courses developed partially with BIM technology.
(grey)	Courses not modified with BIM technology.

Fifth-year work plan and the educational outcomes:

This year, more BIM efficiency is achieved by studying advanced BIM concepts, construction contracts, operations, and project management, learning how to plan and link the model to data, obtaining full project information in addition to raising awareness of cultural and organizational influences and the change needed to adopt BIM.

The final year reflects the advanced level of acquired BIM skills, as this year:

- Deliver the architectural design model in the REVIT module.
- Conducting simulations to represent the 4D & 5D project within the project planning and management course using Navisworks
- Extract schedules of quantities and specifications from the Revit model.
- Prepare a typical BIM protocol.

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- Using Revit + GIS in the city planning course
- Learn about new ways of working on engineering projects.

Graduation Project:

Throughout this year, students should deliver the final BIM model in Revit format, 3D presentation & rendering, construction analysis, and all model information and specifications as well as quality presentation.

Concept:

1. Knowledge of managing BIM through planning, scheduling, and costing.
2. Knowledge and understanding of regulatory and legal frameworks and change management.

Technology (Practical and Professional NARS Skills):

1. Formatting BIM graphics into a shared file and detecting and resolving conflicts using Navisworks.
2. How to conduct planning, scheduling, and cost estimation.
3. The importance of construction contracts and how to link the model to the data.

Process (Intellectual NARS Skills):

1. Flexible data collection, analysis, and return.
2. Perform scheduling plan and cost estimates and how to link BIM model with plan information to perform simulation and project representation 4D& 5D.

Integration & Collaboration (General Transferable Skills):

1. Developing architectural models in cooperation with other engineering disciplines.
2. Provide an integrated BIM model.

Table 6: Fifth-Year Courses

First Semester	Second Semester
Architectural Design 5 Revit + Autodesk 360 ❖	Graduation Arch. Design Project Revit ❖
City Planning Revit + GIS ❖	
Quantities & Specification Revit ❖	
Project Management Revit+Navisworks/Primavera ❖	
Real estate legislation ❖	

Legend	
(dark blue)	Courses developed entirely with BIM technology.
(light blue)	Courses developed partially with BIM technology.

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Chart of tools, competencies, and educational outcomes for the third level according to ABET

Third Level (4th , 5th year)

Tools

- (Modelling Tool) :Revit Arch. Advanced – Revit Structure – Revit MEP
- Energy Simulation Tools (7D) :Ecotect or Add-in software for revit (Insight)
- Coordination Tools : Revit (Shared Coordinates – Clash Detection)– Navisworks (Clash Detection)
- Managing Tools :Navisworks (4D & 5D) – Primavera
- GIS (Store, visualize, manage and analyze geographic data).
- Cloud BIM Applications:Autodesk BIM 360

Competencies & Skills

- Modeling skills: knowledge of databases – knowledge of various BIM programs – advanced level in model presentation and presentation (related to technologies)
- Administrative skills: information exchange processes between students to build BIM models to extract and reuse information or project components (linked to processes)
- Theoretical skills: knowledge of guidelines and contractual arrangements (linked to policies)

ABET Standard

- Use of modern software and technologies in design and simulation and the ability to express construction drawings graphically and technically(K)
- An ability to understand and describe the essential foundations of the building construction process and structure systems(C, E)
- The ability to coordinate, work collaboratively, communicate effectively, and exchange information and models with different disciplines(D, G)
- BIM contributes to the documentation and distribution of responsibilities among team members .(F, D)
- Learn to manage projects via BIM, link the model to project data, and be able to perform simulations (4D & 5D). (J)
- Learn to apply BIM and GIS integration. (H)
- Learn the uses of ADD-in within Autodesk Revit. (I)
- Online self-learning as a complement to the educational content. (I)

Figure 4: A chart of tools, competencies, and educational outcomes for the third level according to ABET standards

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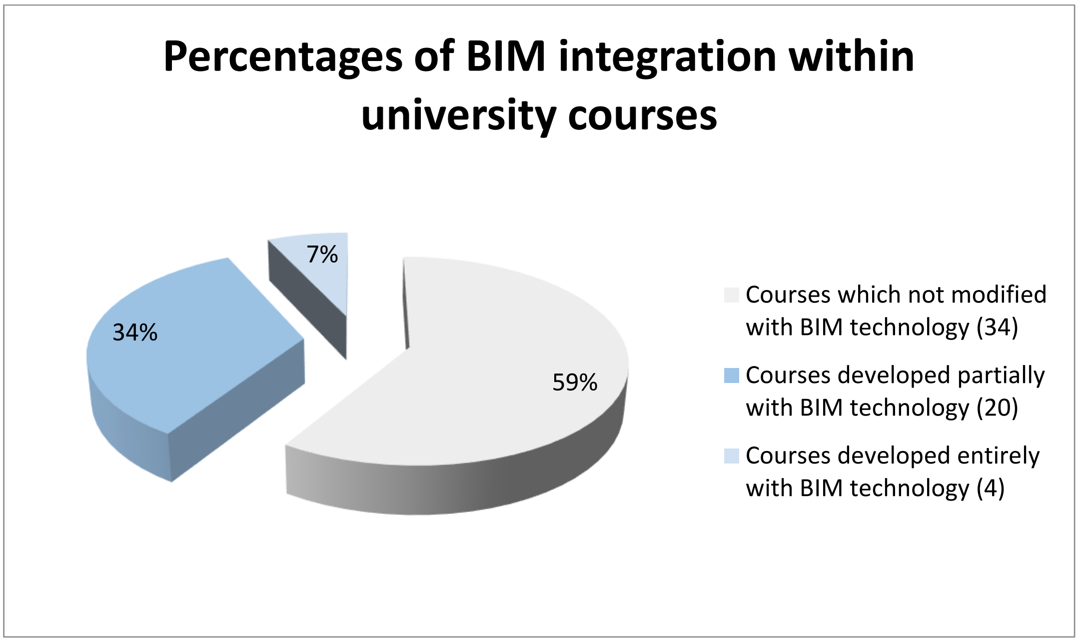

Figure 5: Percentages of BIM integration within university courses

New elective course:

Offering an elective course helps transition to advanced design levels and enhance skills with advanced BIM tools such as Rhino/Dynamo that contribute to the design of organic models and complex shapes.

Professional training:

Integration of BIM within practical university training contributes to acquiring new information and an advanced level about BIM as an administrative platform, BIM roles, and working with engineering disciplines and professionals to develop simulation plans and detect conflicts between models, enhances skills and qualifies them to work after graduation with high efficiency.

Framework Validation:

The developed proposal has been validated through interviews with faculty and administrative staff members to identify the developed proposal and gather feedback and recommendations.

Six participants identified the challenges that could impede the processing of embedding BIM and the proposals to overcome them.

It found that there was agreement on the clarity of the proposal in terms of structure and concept for the participants. Also, most participants agreed on the proposal and its applicability, except for one participant, due to the difficulty linking the courses. It is difficult at first, but in architecture, it is essential to make a practical connection between architectural design and design-related fields and subjects according to the teaching level.

It is possible to take into consideration some of the participants' suggestions to enrich the proposal to include BIM in the Faculty of Architecture - Damascus University, including cooperation with the Research Center and coordination with government and private agencies (the Engineers Association and the Studies Company), also, from the experiences of universities that have adopted BIM in their curricula to reach a proposal that fits the educational reality.

The responses also indicated that all participants support the idea of cooperation with other disciplines. Therefore, the direct participation of students in a multidisciplinary collaborative project and working as one team qualifies them to enter the labor market with new skills and greater efficiency.

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The participants also agreed with the idea of training as part of the evaluation and the need to provide opportunities to apply BIM realistically during education. All participants also agreed that the inclusion of BIM contributes to increasing engineering knowledge and improving skills, leading to meeting the requirements of the AEC industry.

Participants also expressed their approval of the importance of the educational outcomes presented within the proposal.

The participants agreed with the proposal of starting to teach BIM Concepts in the first year, except for one participant who suggested not teaching BIM in the first year and starting teaching BIM tools in the second year. Also, the participants agreed with the proposal to begin teaching digital BIM tools partially in the computer skills course.

The answers about the third-year work plan varied among the participants. Three participants expressed their support for the work plan. One participant chose not to agree, while one answer was neutral on the architectural design course in the third year and proposed to start modelling one space in the architectural design course in the first semester and then move to model a group of spaces in the second semester. It is possible to implement this proposal following the content of the architectural design course. Another question about the fourth-year execution courses, there were two neutral answers to a question that suggests dedicating executive design projects for high-rise buildings and wide spans could be done collaboratively between other disciplines. One of the participants suggested not cooperating with other students' engineering disciplines, and cooperating with engineering companies or the Engineers Syndicate continuously during the university education stage.

Most of the participants agreed with the fourth-year work plan. One participant proposed to partially include BIM in the environmental science course in the first semester by presenting a practical project. One participant chose neutrality and suggested applying BIM only to one project within the academic year.

Most participants expressed their approval of the work plan presented in the fifth year, which includes the objectives, educational outcomes, acquired skills, and competencies. One participant answered neutrally due to the difficulty of applying the proposal to the graduation project, given that the graduation project is the outcome of the information the students learned during the five years. The graduation project is the final output of a five-year study, so students should present their graduation project with the competencies gained over these years from BIM. Therefore, it is essential to show the ability to integrate BIM into the architectural engineering project following the graduation project's requirements. Because of this, the proposal aims to embed BIM partially in the graduation project course.

Most participants agreed to offer a new elective course, while one participant chose neutrality and suggested replacing the new elective course with an engineering development course after graduation. There was another question about identifying BIM as a base requirement in fourth-year vocational training while the responses varied with three agreements, one answer neutral, and one negative answer.

8. Conclusion

Because of the importance of the next stage in Syria, the stage of reconstruction, and the start of some companies to move towards the application of BIM, it was necessary for educational institutions to develop their curricula to keep of recent developments and digital transformation, and to qualify new graduates with the necessary competencies and expertise.

This study provided a deep understanding of the capabilities and advantages of BIM and its importance in education and the development of a framework and a detailed plan for the process of including BIM in the Faculty of Architecture - Damascus University as a case study to obtain a comprehensive picture of the implementation process. Incorporating BIM within education defined according to IMAC - BAF within the NARS-ABET Engineering Education Standards and identifying the acquired competencies by reviewing and analyzing relevant studies and benefiting from the conclusions to find optimal solutions for the application.

The development of the BIM educational framework utilized three ascending levels through Five years and take into consideration the different learning outcomes of BIM in theory and concept,

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tools and techniques, process and practice, and collaboration and integration, and achieving these educational outcomes according to ABET standards.

The validity of the proposed framework was validated and evaluated by academic staff members in the College of Architecture by conducting qualitative interviews and analyzing the results. The results showed acceptance of the proposed framework and interest in BIM integrating process into architectural education and the educational outcomes provided by BIM.

9. Recommendations & Future Approach:

- Work to achieve a link between the science of design and the fields and study materials related to it from the field of environmental, construction, and interior design according to the teaching level, which achieves the concept of integrative education in the architectural curriculum in a practical way.
- The BIM integrating process within the engineering education sector contributes to the rapid digitization of the workflow of the construction sector.
- At the start of the implementation phase, curriculum modifications, and student feedback must be continuously monitored and evaluated.
- Practical application of HBIM technology within workshops and realization of the role of BIM in the design, construction, and renovation of historical buildings.
- Benefit from the main criteria map for the BIM application maturity ladder in architectural education.
- Examination of the proposed model by an international BIM maturity standard such as the education model axis proposed by (Sukkar, B.)

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