Faculty of Engineering
Department of Architecture

PhD Dissertation

A Framework for BIM Excellence in Architectural Education in Libya

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Declaration

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination, leading to the award of a degree.

PhD Candidate: Ozaer Zaed

Signature:

Date: 05/09/2024

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Abbreviations

AECO	Architecture, Engineering, Construction, and Operation
AIA	The American Institute of Architects
AiC	The Academic Interoperability Coalition
BAF	BIM Academic Form
BEP	BIM Execution Plan
BIM	Building Information Modelling
BIMBOK	BIM Body of Knowledge
BIMEX	BIM Excellence
BIMEXAE	BIM Excellence in Architectural Education
CDIO	Conceive-Design-Implement-Operate
CK	Content Knowledge
ESD	Education for Sustainable Development
HE	Higher Education
ICT	Information and Communication Technology/Technologies
IFC	Industry Foundation Classes
IMAC	Illustration, Manipulation, Application, And Collaboration
IPD	Integrated Project Delivery
LSC	Learning And Skills Council
NAAB	National Architecture Accrediting Board
NBS	National Building Specification
NFB	National Federation of Builders
PCK	Pedagogical Content Knowledge
PK	Pedagogical Knowledge
QCA	Qualitative Comparative Analysis
RIBA	The Royal Institute of British Architects
RICS	The Royal Institution of Chartered Surveyors
TCK	Technological Content Knowledge
TK	Technological Knowledge
TPACK	The Technological Pedagogical Content Knowledge
TPK	Technological Pedagogical Knowledge

Glossary

Glossary	Definition	References/notes
Architecture, Engineering, Construction, Operation (AECO)	The lifecycle of a building encompasses design, construction, occupancy, and ongoing operations, involving professionals from architects, engineers, construction professionals, facility managers, and building owners, all working together to achieve a common goal of delivering a high-quality building that meets the needs of its users.	MARSBIM (2021)
BIM Education	The process of teaching and learning BIM concepts, skills, and knowledge, to prepare students for collaborative project-related activities in AECO disciplines.	AIA-CA (2012)
BIM Educational Programme Maturity Matrix	A tool or matrix used to assess and categorize the level of integration and maturity of BIM within an educational institution's program. It offers a systematic approach to measuring the development and implementation of BIM education. It can be used as a reference tool for institutions to assess their progress and identify areas for improvement.	Wu et al. (2021)
BIM Excellence	A set of guiding principles aimed at achieving the highest standards of BIM integration within an educational institution's programme. It goes beyond simply teaching BIM software and skills, focusing on creating a holistic learning environment.	Self-definition
BIM Programme	A structured sequence of educational activities designed to achieve specific learning objectives in BIM over an extended period such as courses, modules, units, or subjects.	UNESCO (2012)
Building Information Modelling (BIM)	BIM is the foundation of digital transformation in the AECO sectors. BIM is the holistic process of creating and managing information for a built asset. Based on an intelligent model and enabled by a cloud platform, BIM integrates structured, multi-disciplinary data to produce a digital representation of an asset across its lifecycle, from planning and design to construction and operations.	Eastman (2018); Autodesk (2023)
Education Infrastructure	The management of software, hardware, facilities, and teaching resources necessary for effective BIM integration in educational settings.	Self-definition
Education Partnership	Collaborative initiatives between academic institutions and/or industry professionals to enhance the quality and relevance of BIM education.	Self definition
Education Process	The planning, implementation, and evaluation of teaching methods and practices to optimize student learning and proficiency in BIM.	Self definition
Education Product	A comprehensive and inclusive curriculum encompassing educational strategies, tactics, and operations that equip students with the necessary BIM skills and knowledge for professional success.	Self definition

Glossary	Definition	References/notes
Educational Framework	A structured system of principles, guidelines, and best practices for guiding the planning, decision-making, and implementation of BIM education within a specific context.	Oxford University Press (n.d.)
University Vision	The overarching institutional commitment to integrating BIM into the curriculum, emphasises innovation, collaboration, and alignment with digital AECO needs.	Wu et al. (2021)
Professional Development	It involves a varied range of specialized training on all aspects of BIM. This includes formal education to enhance expertise and effectiveness, aiming to improve knowledge, competence, and skills in BIM utilization.	Wu et al. (2021)

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Abstract

The integration of BIM in architectural education is essential for equipping graduates with essential, industry-relevant skills increasingly demanded by the AECO sectors. BIM fosters a collaborative, data-rich environment that enhances project visualization, efficiency, and accuracy, essential for contemporary architectural practices. Integrating BIM into the architectural programme ensures students are adept in cutting-edge technologies and methodologies, thus enhancing their employability and readiness to meet professional challenges. This alignment between educational outcomes and industry needs is crucial for developing a competent and competitive workforce in AECO sectors, which has experienced a digital transformation driven by BIM. However, architectural education remains in the initial stages of incorporating BIM into its curriculum. This PhD study addresses this gap by developing a novel educational framework, BIM Excellence in Architectural Education (BIMEXAE), for BIM integration within architectural education. BIMEXAE intends to bridge the disconnect between architectural education outcomes and AECO sectors' needs in the context of BIM.

A mixed-methods research approach was employed for an exploration of various aspects of BIM and to identify best practices for its implementation in AECO sectors and architectural education and related disciplines. This approach combined literature reviews, questionnaire-based surveys, and framework development. The literature review examined the global BIM adoption patterns and identified prevalent challenges in both educational and professional domains. The survey was strategically adapted to collect data from two different perspectives: professionals actively engaged in the Libyan AECO sectors, and educators shaping architectural education. This dual approach revealed a pervasive lack of BIM awareness among professionals and the infancy of BIM adoption in Libya. Self-learning through online resources emerged as the primary skill acquisition method, highlighting the need for readily available training opportunities and a competent BIM-oriented workforce. Educators expressed their desire to integrate BIM but acknowledged constraints including lack of awareness, reluctance to change, lack of suitable resources, lack of qualified staff, lack of academic and professional collaboration. Their perspectives emphasised the need for proper planning, practical training, and enhanced industry collaboration to bridge the academia-industry gap.

To address these challenges, this study proposed a BIMEXAE Framework. This framework serves as a technical solution, outlining a series of strategies based on pre-determined criteria: curriculum design and development, education infrastructure development, professional development, and educational partnerships. The BIMEXAE framework is consists of the following two key components:

1) A four-phase procedure for BIM programme development: This procedure establishes a strategic framework based on the defined evaluation criteria. It aims to support institutional planning efforts for integrating BIM within architectural education.
2) A four-year BIM-integrated curriculum: This curriculum guides the full implementation of a BIM-focused programme for undergraduate architectural education in Libya.

This framework encourages consistent alignment of architectural education with the growing demands of the AECO sectors. Assessment based on consultations with Libyan architectural educators confirm the framework's practicality and potential to redefine undergraduate architectural education in Libya, fostering graduate’s adept in BIM technology and well-equipped for the dynamic AECO sectors.

This research adds value by contributing to the understanding of BIM adoption challenges in a developing nation such as Libya, this research offers valuable insights for architectural educators, practitioners, policymakers, and institutions. The BIMEXAE framework provides practical guidance for the effective implementation of BIM education, aiming to enhance graduate and professional preparedness, promote the growth of the AECO sectors in Libya, and ultimately improve project outcomes through the adoption of BIM.

Chapter 1: Introduction

This chapter provides a comprehensive overview of the research undertaken and documented in this PhD dissertation. To provide a thorough introduction to the research and dissertation, this chapter is structured in the following main sections: (1) Research overview; (2) problem statement; (3) research question; (4) research aim and objectives; (5) research design and methods; (6) research outcomes; (7) research implications; (8) research limitations; and (9) dissertation structure.

1.1 Overview

The AECO sector is one of the most significant global industries, being the primary source of employment and economic growth while also creating the built environment in which all other socio-economic and cultural activities occur. However, the sector has been criticised for its low economic productivity and performance; secondly, its high level of waste and its chronic environmental impact (Dakhil, 2013; Kirchberger, 2020). Many developed, and developing countries have encountered various issues and challenges with the AECO sectors, including a lack of management and strategies, low levels of expertise, and a shortage of existing data related to the construction location, resulting in delays and cost overruns (Shibani and Gherbal, 2018). These problems have been considered significant obstructions to developing the AECO sectors in developing countries. They have also increased further due to poor communication and a lack of coordination and collaboration among companies, shareholders, stakeholders, and professional institutes (Budayan and Arayici, 2021). This has arisen as a result of each operating individually rather than cooperatively.

The AECO sector is being transformed by adopting digital technologies such as BIM. Therefore, the use of BIM has expanded inside construction and architectural firms, particularly in developed countries, i.e., the UK, the US, and Australia (Ahn and Kim, 2016; Lopez-Zaldivar et al., 2017). In addition, professional interest in BIM-integrated AECO practices has increased worldwide, including among members of the Royal Institute of British Architects (RIBA) and the National Building Specification (NBS), which conducts an annual survey on usage and awareness of BIM, identifying that it has now become almost universal. NBS (2012–2019) found that the percentage of BIM adoption across all AECO sectors increased during the last decade. The adoption of BIM in construction projects has considerably influenced project productivity and performance (NBS, 2019), particularly as it is connected to all fundamental dimensions of a project, i.e., design, data technology, and development.

BIM is formed with a group of correlated techniques, systems, and skills facilitating the modelling of projects, in particular the significant aspects of construction design, so providing comprehensive information during the initial design, then projecting data relevant to the complete life cycle of a building (Eastman et al., 2011; Oduyemi and Okoroh, 2016). Enshassi et al., (2016) emphasised that the benefits of using BIM during the construction phase include: providing accurate scheduling, providing more accurate cost estimation, improving visualisation, improving coordination, improving communication, and performing quantity take-offs accurately. In addition, BIM utilisation forms a preliminary factor for integrating various methods and strategies used in architectural practice, which assist in enhancing the efficiency of interrelated processes, i.e. planning, designing, analysis, and construction. Thus, BIM is a digital model that provides data during all project stages (Eastman, 2018).

Although several studies have demonstrated the added value of BIM for the AECO sectors, its use continues to face numerous challenges, particularly in developing countries. Such barriers are due to BIM being a new phenomenon focused on renewing latent and traditional architectural practices impacting diverse stakeholders and professions. These challenges include (1) a lack of any standardised approach, (2) resistance to change, (3) the high cost of BIM applications, (4) a lack of client demand, and (5) a lack of appropriate training (Boton and Forgues, 2018; NBS, 2018, 2019; Saka et al., 2020). This highlights that the main obstacles encountered in the AECO sectors in developing countries could be overcome by providing adequate planning and training in BIM use for designers, architects, and engineers (Azhar, 2011; Walasek and Barszcz, 2017; Osman, 2019).

AECO practitioners and academia have recognised that a substantial requirement from the AECO sectors concerns the integration of BIM into education programmes in architectural education and related disciplines (Abdirad and Dossick, 2016). This has resulted in many universities now offering BIM courses as part of architectural programmes, while most of the remainder are moving towards integrating BIM into their curricula (Joannides et al., 2012; Abbas et al., 2016). However, universities need to acknowledge the importance of BIM education, teaching techniques, and programmes to overcome barriers to its incorporation within architectural curricula (Sacks and Pikas, 2013). There has been much previous discussion of how BIM is currently being utilised globally in teaching architectural students, including whether it should be incorporated as an independent theme or put forward as the primary topic (Abbas et al., 2016; Shelbourn et al., 2017).

Numerous obstacles hinder the provision of quality architectural education in many developing nations including insufficient planning, poor management standards, and an outdated curriculum (Khalil and Halis, 2017; Osman, 2019). This hinders the educational system's ability to equip students with the necessary skills and knowledge related to the AECO sectors, (Osman and Baldry, 2017), impeding productivity and performance across various AECO sectors. Moreover, the absence of proper training in Information and Communication Technologies training impedes technology implementation, preventing these countries from fully harnessing its potential advantages, such as streamlined information processing and sharing.

Universities can play a critical role in preparing future AECO professionals with advanced digital technology, by incorporating BIM and relevant skills into its curriculum, aligning with the evolving job market demands (Sacks and Pikas, 2013). Equipping graduates with BIM competencies will enhance their employability and contribute to meeting the global demand for skilled BIM professionals.

1.2 Problem Statement

The AECO sectors have undergone a digital revolution, driven by BIM which requires new skillsets from educators, students, and professionals. This shift poses a significant challenge for architectural educators in how to effectively integrate BIM knowledge and skills into existing undergraduate architectural programmes and curricula without compromising the core principles of architectural education (Liu, 2012; Abbas et al., 2016; Shelbourn et al., 2017).

The need for BIM integration with architectural education arises in response to the demand for digitalisation across AECO sectors (Ahn and Kim, 2016; Lopez-Zaldivar et al., 2017; Eastman, 2018), and it has been incorporated into architectural education in related subjects (Clevenger et al., 2010) for students to develop skills and competence (Solnosky and Parfitt, 2015; Olugboyega and Windapo, 2019). In addition, there has been a wide range of academic practices to integrate BIM into teaching and learning in related subjects with focuses on:

- Teaching strategies (Clevenger et al., 2010; Liu et al., 2021; Mahran et al., 2022),
- Methods and teaching materials (Solnosky and Parfitt, 2015; Ozcan-Deniz, 2016; Shelbourn et al., 2017; Olugboyega and Windapo, 2019), an
- Curriculum design and learning outcomes (Abdirad and Dossick, 2016; Coates et al., 2018; Liu et al., 2021).
- Students' perceptions and requirements (Zou et al., 2019; Isanović and Çolakoğlu, 2020).

Despite these initiatives to introduce BIM into architectural education, a comprehensive approach and strategic plan remain absent for its adoption in undergraduate architectural education (Maharika et al., 2020; Böes et al., 2021). This presents a significant educational challenge in how to introduce BIM early and progressively develop students' skills to reach professional proficiency by graduation. These challenges are particularly significant in developing countries, where BIM awareness and adoption within academia are limited. In addition, architectural schools lack incentives and resources for BIM implementation, and government support alone is insufficient (Sacks and Pikas, 2013; Oduyemi and Okoroh, 2016). Therefore, there is a call for a comprehensive approach through collaboration between governmental authorities, academics, and professional practices to discuss and address the current and future trends of BIM education implementation within architectural education and the broader AECO sectors.

1.3 Research Question

What is the most effective and optimal approach to integrating BIM education into undergraduate architectural programmes, preparing future professionals for the evolving demands of digital technologies in AECO sectors?

1.4 Research Aim and Objectives

The research conducted for this PhD study aims to develop a new educational framework for BIM integration within architectural education in Libya, with the potential to be generically applicable in other countries. This framework is called BIM Excellence in Architectural Education (BIMEXAE). The BIMEXAE can help academics facilitate the incorporation of BIM within architectural programmes through the consistent integration of structured BIM knowledge curriculum design and course delivery to fully prepare future architectural professionals.

In order to achieve the overall research aim, this research has the following four objectives:

- Objective 1: To critically review the status of BIM and identify best practices for its implementation in AECO sectors and architectural education.
- Objective 2: To investigate and evaluate the status of BIM implementation and its associated challenges within Libyan AECO sectors and architectural education.
- Objective 3: To develop a novel educational BIMEXAE framework for BIM integration within architectural education in Libya, with the potential to be generically applicable in other countries.
- Objective 4: To assess the BIMEXAE framework through consultations with architectural educators in the context of BIM integration within architectural education in Libya.

1.5 Research Design and Methods

This research employs a mixed methods approach to achieve the research aim and objectives. The research process involves four stages: research planning, research process, research development, and research outcome. These stages provide a structured research roadmap for investigating the status of BIM adoption and its incorporation into architectural practice and education. The entire research process is presented in **Figure 1.1**, with different methods and research designs employed at each stage to achieve research outcomes.

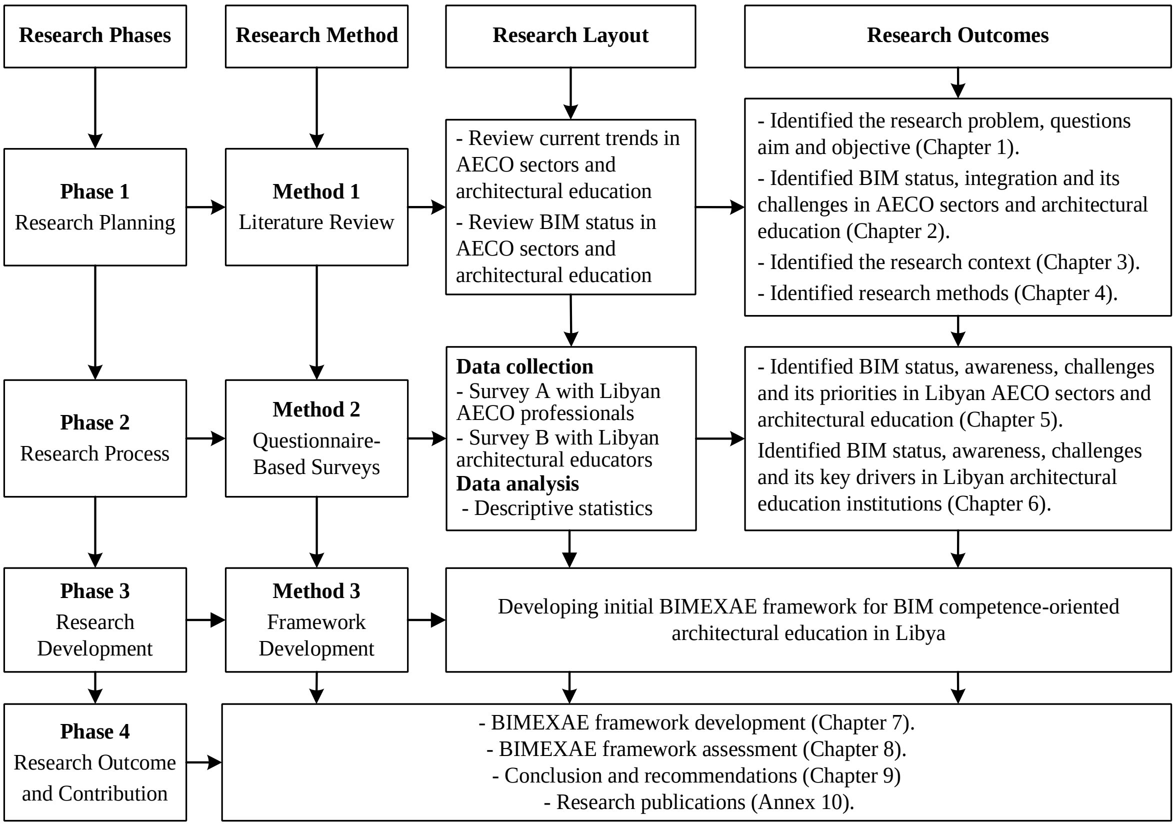

Figure 1.1: Research roadmap

Phase 1: Research Planning

The research planning phase begins with an in-depth literature review on architectural education and practice in relation to the use of BIM technology in order to identify best practices for its implementation in AECO sectors and architectural education. The literature review aims to identify the research problem, which consists of the challenges associated with integrating BIM into architectural education. In addition, the status of BIM adoption in AECO sectors and architectural education are investigated for a comprehensive understanding of the topic. The research outcomes of this stage include identifying the research problem, question, aim and objective, identifying the research method, identifying BIM status, integration, and its challenges in AECO sectors and architectural education, and identifying the research context.

Phase 2: Research Process

The research process phase involves collecting and analysis the data from two different groups: professionals and educators in the Libyan AECO sectors and architectural education. This method ensures an in-depth understanding of the perspectives and experiences of academics and professionals. The surveys collect information on BIM awareness, status, obstacles, and key drivers in Libya's AECO sectors and architectural education. The data collected through the surveys is then analysed using descriptive statistics to summarise and interpret the findings. The outcomes of this phase include the identification of priorities in

BIM-oriented architectural education, the BIM awareness and status in Libya, and the challenges and key drivers for BIM in the AECO sectors and architectural education.

Phase 3: Research Development

The research development phase seeks to establish a new framework that incorporates all the requirements for integrating BIM into the core architectural programme and other relevant disciplines. The framework is created by synthesising the data from the literature review, survey results, and existing global academic initiatives in BIM integration with education. Developing a framework is essential because it provides a structured method for the effective incorporation of BIM into the curriculum. The outcome of this research stage is the framework's development, which is then proven by Libyan educators by collecting their feedback, in order to ensure its suitability for Libyan architectural education.

Phase 4: Research Outcomes and Contribution

The final phase of the research includes finalising the framework, framework assessment and conclusion and recommendations. The framework development process iteratively refines and improves the previously assessed framework. This phase ensures that the final framework is exhaustive, applicable, and relevant to the architectural education context in Libya. The conclusion and recommendations section provides a concise summary of the research outcomes and a synthesis of the previous phase’s findings. In addition, it provides specific recommendations for stakeholders in architectural education, policymakers, and institutions to improve BIM implementation in education. Additionally, this PhD study has contributions to the body of knowledge by a series of publications (See **Annex 10**), each publication addressing unique facets of BIM-oriented architectural education.

1.6 Research Outcomes

The main outcome of this PhD study is the development of the BIMEXAE framework for BIM competence-oriented architectural education in Libya, which draws from two key sources:

- Global best practices: BIMEXAE incorporates optimal practices of BIM implementations worldwide, particularly in the United Kingdom, the United States, and Australia, where the AECO sectors and architectural education have embraced BIM with notable success. This ensures the roadmap draws upon established and proven methods.
- Local expertise: Surveys with Libyan professionals and academics provided essential perspectives and contextual considerations specific to Libyan architectural education. This ensures that BIMEXAE is suitable to the unique needs and challenges of integrating BIM in Libya.

The resulting framework, BIMEXAE, provides guidelines for effectively integrating BIM into architectural programmes and curricula. By leveraging both global best practices and local expertise, BIMEXAE offers a practical and contextually relevant roadmap for transforming architectural education in Libya.

1.7 Research Implications

The significance of this research is the provision of the BIMEXAE framework for BIM competence-oriented architectural education in Libya. BIMEXAE provides a structured approach for Libyan universities to integrate BIM competences into their architectural programmes. This framework can guide curriculum design, course delivery, and faculty development initiatives. In addition, BIMEXAE can serve as a benchmark for BIM education in other countries. Architectural programmes worldwide can compare their current BIM integration strategies with the framework to identify areas for improvement.

Furthermore, by adopting BIMEXAE, universities can equip their graduates with the essential BIM skills demanded by the construction industry. This will significantly enhance their employability and prepare them for contemporary building practices. In turn, graduates with BIM expertise can defender the adoption of BIM within architectural firms, accelerating the industry's transition towards this transformative digital technology.

1.8 Research Limitations

All research carries inherent limitations that can influence the scope and generalisability of its findings. This section outlines the specific limitations encountered during this study on developing a BIMEXAE framework for Libyan architectural programmes, providing context for interpreting the research results.

- Scope: The study focused only on developing a framework for BIM education in architectural education in Libya, excluding other disciplines or regions. Future research could expand the scope to include a broader range of disciplines and regions, providing a more comprehensive understanding of BIM education. For example, a future study could investigate BIM education across various engineering and construction management programmes.
- Student perspective: While student perceptions are invaluable for evaluating BIM education, this study primarily gathered data from educators and professionals. Due to the current state of BIM education in Libya, incorporating student opinions was not feasible. Future research would benefit from including questionnaires or surveys specifically targeting students' perspectives on BIM education to gather valuable feedback on the proposed framework and identify potential areas for improvement.
- University level focus: This study concentrated on BIM education at the university level. Further research could explore the relationship between BIM education and industrial development, examining whether BIM education is driving advancements

in the industry or being driven by them. This understanding would inform the optimal approach to developing and implementing BIM education programs.

- Framework validation: The BIMEXAE framework underwent assessment through questionnaire-based survey with architectural educators, verifying that it meets the desired level of performance in this study. However, conducting optimal validation through empirical methods like real-world case studies requires more time and resources than were available within the scope of this study. Future research could validate the framework's applicability and effectiveness through real-world case studies in architectural programmes, providing stronger evidence of its impact and potential for replication.

1.9 Dissertation Structure

This research is presented in nine chapters, as shown in **Figure 1.2**, which can be grouped into three major categories. Chapters one to four provide a debate for research introduction, research methodology, literature review, and research background on Libya; chapters five and six present discussion, and findings; and chapter seven aims to examine the BIM integration framework in Libya's undergraduate architectural education. Chapter eight presents the results of the framework assessment. Chapter nine summarizes the significant findings of the research, limitations, recommendations, and suggestions for future research.

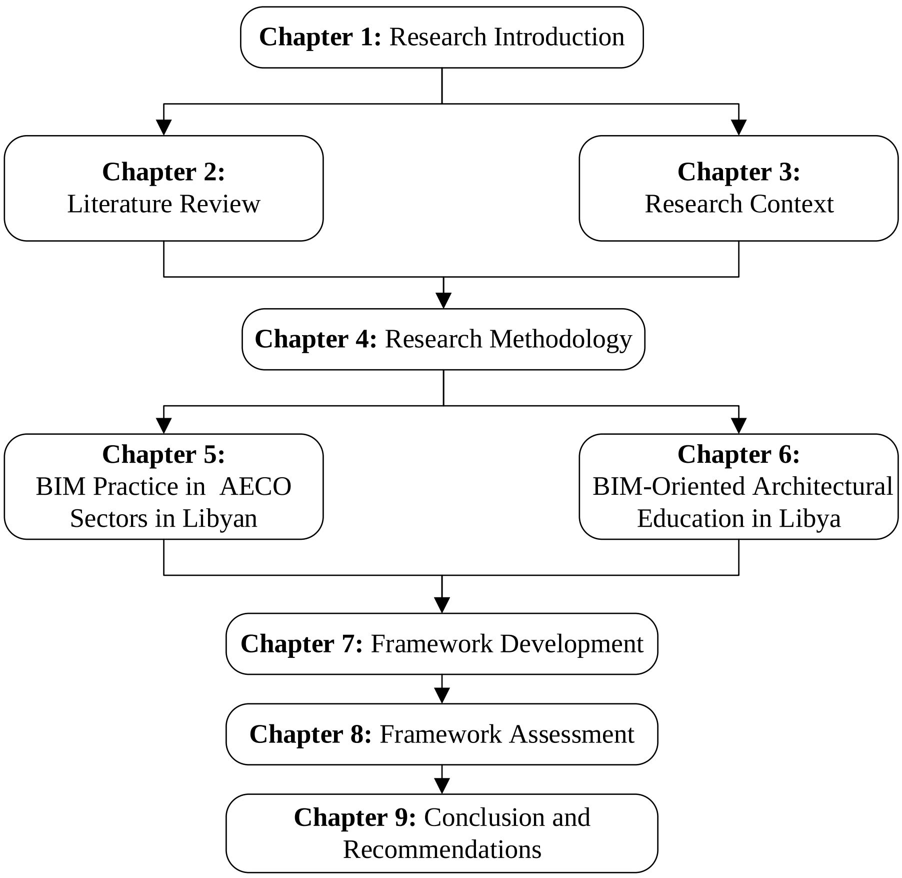

Figure 1.2: Dissertation structure

Chapter 1: Introduction

This chapter provides an introduction to the entire research. It commences with a broad overview of the research background, followed by a clear presentation of the problem statement, research questions, and the aims and objectives of the study. Additionally, this chapter outlines the research methodology and its application, discusses anticipated research outcomes, and acknowledges the research's implications and limitations. Lastly, the chapter offers a brief overview of the thesis structure for the reader's guidance.

Chapter 2: Literature Review: BIM in AECO sectors and Architectural Education

This chapter reviews the literature review on BIM status in the AECO sectors and architectural education. Aligned with Objective 1, the chapter begins with an overview of BIM and its definition. Then, the growing demand for BIM within the AECO sectors and the benefits of BIM adoption in the AECO sectors. This is followed by an examination of some of the BIM implementation challenges. In addition, this chapter provides an in-depth examination of how BIM has been adopted and taught in architectural education. This chapter also explains the state of BIM in the AECO sectors and architectural education worldwide, as several developed countries have established BIM adoption plans in their AECO sectors of architectural education.

Chapter 3: Research Background in Libya

This chapter provides a comprehensive overview of the historical, social, and economic factors that shape architectural education in Libya. It highlights the challenges encountered in undergraduate architectural education within developing countries like Libya, which are different due to the nation's historical and cultural context. Furthermore, this chapter emphasizes the significance of addressing the critical challenges of integrating BIM technology into architectural education and practice.

Chapter 4: Research Methodology

This chapter discusses the research methodologies used in this PhD study. This chapter also covers the research design to put forward the research framework for collecting data. Moreover, Chapter 4 provides the key variables and considerations supporting why questionnaire-based surveys are a suitable research tool for this study. The approach used in this study was designed to accomplish the research aim and objectives.

Chapter 5: BIM Practice in Libya

This chapter discusses the process of conducting Survey A and the collection of primary data from the Libyan AECO sectors. This chapter corresponds to Objective 2 of this research in order to discuss numerous significant topics, including the questionnaire-based survey distribution, the preparation stage before the initiation distribution stage, and the processes involved in the data analysis process, focusing on technical procedures. This chapter summarises the research findings on BIM concerning the challenges associated with its adoption in the Libyan AECO sectors.

Chapter 6: BIM-Oriented Architectural Education in Libya

This chapter discusses Survey B, which was used to collect primary data from undergraduate architectural schools in Libya, corresponding to Objective 2 of this research. It details Survey B planning and process and how it was done and analysed. The chapter discusses Libyan architectural education institutions' status and readiness to integrate BIM into architectural education.

Chapter 7: Development of the BIMEXAE Framework

This chapter describes the development of the BIMEXAE framework, which corresponds to Objective 3 of this research. The development of this comprehensive framework is informed based on findings from the previous chapters. The chapter also emphasises the need for a BIMEXAE framework. Finally, the chapter presents a comprehensive overview of the evolved framework, summarizing the key facets that have contributed to its final iteration.

Chapter 8: BIMEXAE Framework Assessment

This chapter presents the findings from consultations with architectural educators aimed at assessing the BIMEXAE framework in the context of integrating BIM within architectural education in Libya, which corresponds to Objective 4 of this research. Through a questionnaire-based survey, Libyan architectural educators evaluated the framework's components, value, design, applicability, suitability, and effectiveness. The following sections detail the assessment process and its outcomes.

Chapter 9: Conclusion and Recommendations

This chapter presents the conclusive reflection of this study. This chapter thoroughly summarises the research's aim and objectives and how those objectives were achieved during the investigation, summarizing the findings for each. The research's value to knowledge is further described in the chapter. The chapter covers the study's overall conclusions and offers a summary of suggested research directions.

Chapter 2: Literature Review: BIM in AECO Sectors and Architectural Education

This chapter aims to justify the research aim and objectives by discussing the main areas of the literature review. The chapter focuses on establishing the status of BIM and its application in architectural education by reviewing academic initiatives on the teaching and learning of BIM to identify challenges facing its incorporation within the architectural curriculum. The chapter offers reviews and discussions, including (1) BIM definition, dimensions, and maturity levels; (2) BIM implementation and challenges in architectural practice; (3) the need for BIM education in architectural practice; (4) BIM in academia, including its status, curriculum development, implementation, and challenges; (5) global academic initiatives in BIM education development; (6) the importance of BIM education; (7) the need to restructure architectural education and review current frameworks and theories to restructure architectural education to integrate BIM; (8) identification of the research gaps. Finally, the chapter summarises the need to develop a new BIM education framework.

2.1 Understanding Building Information Modelling

2.1.1 Definition of BIM and the Motivation for Its Adoption

There are several difficulties in providing a standard definition of BIM. Previous studies have resulted in a number of definitions based on factors such as (1) the view of the user; (2) the particular work; (3) the type of company; and (4) the established and anticipated benefits.

Several professionals have viewed BIM as a tool and/or a digital construction model. An examination of the different definitions of BIM reveals that it is regarded as (1) a technology/process (i.e. a new way of working); (2) a collection of tools (i.e. software); (3) a digital product or model; and (4) intelligence (Eastman et al., 2008; RIBA, 2012; Mandhar and Mandhar, 2013; NBS, 2019).

BIM has been described as an interaction between processes, policies, and technologies. Thus, it can be seen as “a set of interacting policies, processes and technologies generating a methodology for managing essential building design and project data in a digital format throughout the building's life-cycle” (Succar, 2009).

The following definitions are formulated for BIM as a process and model.

- BIM is a new methodological approach to business processes involving building design, construction, management, and maintenance. When fully implemented, all stakeholders can simultaneously access project scopes, timelines and budgets in a high-quality, reliable, integrated, and fully coordinated manner.
- BIM is a parametric 3D “digital representation of the physical and functional characteristics of a building” (NIBS, 2007). Based on open interoperability standards, it can serve as an information-sharing feature, providing a reliable basis for decision-

making by agents involved throughout the lifecycle of a building (National BIM Standard (NBIMS), 2015).

The concept of BIM has been defined in education as a process of gaining the essential knowledge and skills to meet its requirements (AIA-CA, 2012). Silverio et al., (2016) described BIM education as a continuous learning process. This, therefore, needs to contain: (1) the fundamental aspects of BIM execution; (2) the performance of the participants; and (3) the technical skills required by each individual in accordance with their discipline and role in the construction team.

The philosophy of BIM adoption is to strengthen coordination, collaboration, and communication among construction stakeholders during the lifecycle of a building on a digital asset from its inception (BSI, 2019). Developers and architects view BIM as 3-Dimensional modelling representing a project's physical and numerical features using BIM techniques, applications, tools, crash-finding methods, and code specifications (Tulubas Gokuc and Arditi, 2017). Therefore, the key motivation for its adoption is its link to different applications and technologies supporting various construction projects, including (1) 3D modelling; (2) visualisation; (3) construction/manufacturing designs; (4) construction assessments; (5) site planning; (6) budgeting; (7) power analysis engineering; (8) energy simulations; (9) detection of interference; (10) integration; and (11) facility management.

2.1.2 BIM Dimensions

BIM dimensions are the information included in the building model. This initially indicated the distinction between 2D CAD and 3D dimensional BIM model information. Nevertheless, it has expanded to include other data that may be required to manage during the design, construction, and process of built assets (Hamil, 2021).

There is currently no consensus on the BIM dimensions involved, resulting in various classifications and definitions: 1D to 7D by Saxon (2018); and 3D to 7D by Smith (2014). Besides, the potential of multidimensional BIM has been designated by the term “nD” modelling, which refers to the capability of including a practically limitless number of model dimensions in the building model (Maina, 2018; Hamil, 2021).

After the brief introduction of BIM dimensions and an analysis of the various categories, this study provides a classification for BIM dimensions from 3D to 7D since it grasps the crucial data that must be linked to a BIM model:

3D BIM (Design and Visualisation)

The 3D models in the BIM feature a virtual environment model that includes complete architectural, structural, electrical, and mechanical details. The 3D model is based on the characterisation of construction elements from their manufacturing sources. It is integrated into the software library; thus, the design tool provides accurate and realistic data that allows the achievement of architectural innovation. The 3D model provides the innovation ability to the designer during the design process; thus, the designer is not preoccupied with vertical projections and geometric blocks of the building. Because the design between 2D and 3D is synchronous automatically (Dakhil, 2017). Besides, BIM offers a spatial analysis of the building, enabling collaboration, visualisation of concepts, and simulations realistically for the entire building. Moreover, it allows to reveal the problems and make appropriate decisions to address the issue during the design phase.

4D BIM (Schedule and Time)

4D BIM starts with linking data and activities of the 3D model with a schedule and time, and it is utilised for managing activities associated with construction location planning. 4D BIM assists the architect in revealing the conflict detection or the complexity in an early stage, which helps avoid unexpected changes during the execution. 4D BIM offers tools to manage and display information on the state of the location and the impacts of alteration and supportive communication in numerous situations, which informs workforces in the workplace about any risks or warnings (Jin et al., 2018; Elghaish et al., 2021).

5D BIM (Cost)

5D BIM incorporates all the information and elements related to the building integrated into the cost. It enables the sharing of information among the team in the project, which provides an accurate estimation of the project cost. As a result, 5D can minimize the time used for quantity take-off and permits more time for consultants to review costs and improve the value (Hamil, 2021).

6D BIM (Sustainability)

6D BIM provides information related to sustainability, for example, energy use and resource efficiency. Hence, it covers all elements of building associated with sustainability objectives for improving analysis, understanding, and management across the entire lifecycle of the integrated building (Cory, 2019).

7D BIM (Facilities management)

7D BIM is responsible for asset or facilities management. A BIM model 'asset tagged', provided to the customer or end-user on achievement, filled with adequate information on components and products, operating manuals, warranty data, etc. It is thus possible to reuse the information relying on the BIM model to increase the efficiency of the management, planning, renovation, and maintenance of installations (Borrmann et al., 2018).

2.1.3 BIM Maturity Levels

BIM deployment demands a considerable change in strategic planning, people, processes, and technologies. Adopting maturity models can provide substantial benefits to BIM users by facilitating the required adjustments, which can be divided into levels that can be followed to achieve the intended BIM advantages (Giel and Issa, 2015; Kassem and Succar, 2017). Maturity describes the variety of levels of quality that this type of BIM modelling can achieve. Thus, BIM maturity indicates the repeatability, quality, and degree of perfection of producing BIM models (Kassem and Succar, 2017).

There are an increasing number of BIM maturity assessment methods in which the benchmarking is achievement improvement milestones (or levels) that individuals and organisations strive for or pursue. Generally, the maturity models diverge in terms of the notions they reflect and their suggestions regarding the path to maturity. Most maturity models have adopted the "Capability Maturity Model" (CMM). The CMM model is based on five stages or levels of maturity, commencing with the lower level or primary (Level 1) and culminating with the highest level of continuous improvement process (Level 5) (Dakhil et al., 2015). A typical five-level maturity model is depicted in **Figure 2.1** where level 1 represents initial development and level 5 indicates final improvement. In general, the movement from low to higher levels of maturity means; (1) Better management through minimizing deviations between performance goals and actual results, (2) Improved predictability and forecast by decreasing unpredictability, incompetence, costs and performance, (3) Greater efficiency in achieving predetermined objectives and establishing new, more ambitious ones (Dakhil, 2017).

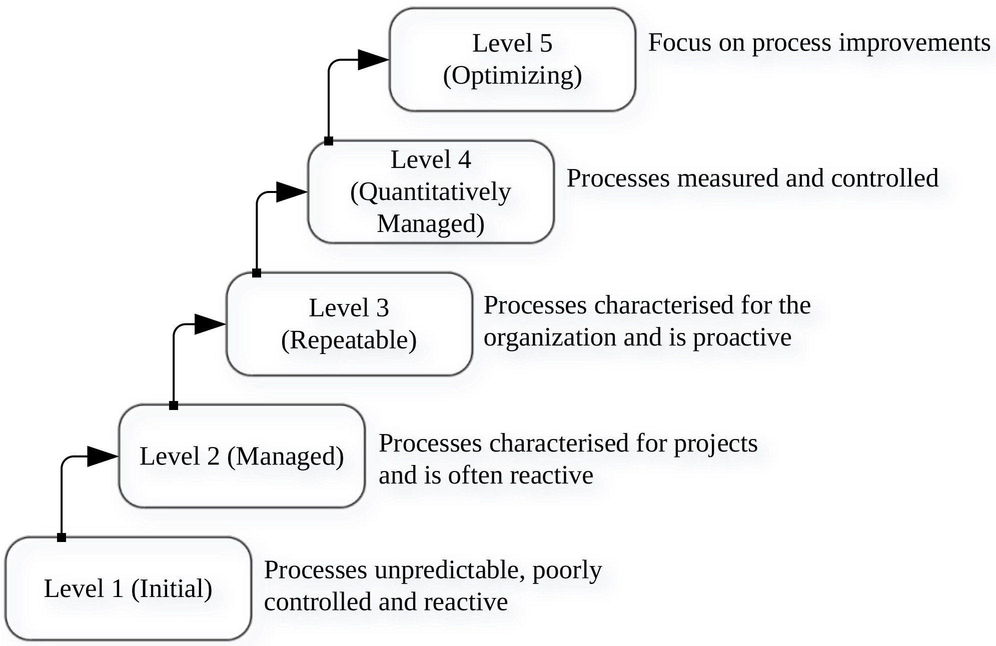

Figure 2.1: The typical five-level maturity model

Therefore, to successfully implement BIM in the AECO sectors, all BIM users should demonstrate their capability to utilize BIM effectively (Brittany Giel and Issa, 2013). CIC Research Programme has developed a BIM Planning Guide for Facility Owners to aid project teams by guiding them through the plan of BIM deployment. A core element of the planning approach highlighted facility owners' need to understand and articulate their intentions for integrating BIM through the asset's lifespan. This guide includes six essential BIM planning components: strategy, information, process, uses, infrastructure, and personnel (**Figure 2.2**). Besides, it consists of an easy-to-understand definition of each maturity level within the planning aspects. The maturity levels range from zero (0), which denotes the absence or non-use of that component inside the organization, to five (5), where the planning component is continuous improvements (Penn State, 2015). This model is regarded as one of the most efficient models for assessing BIM maturity since it has been built specifically for their organisations. The BIM planning guide for facilities managers has clearly outlined the evaluation process.

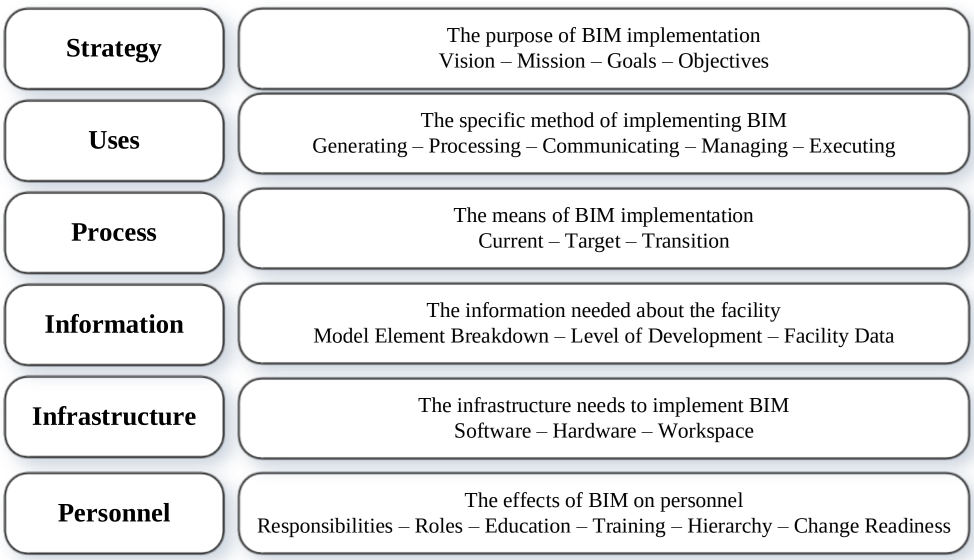

Figure 2.2: The BIM Planning Elements

The UK BIM Task Group developed the BIM Maturity Model which defines four discrete levels of BIM implementation (**Figure 2.3**). This thus became the criteria for evaluating an organization's compliance with the given BIM levels. In the United Kingdom, the government acknowledged that the transition procedure in the AECO sectors in the direction of fully collaborative work inside BIM is gradual, with clearly recognisable milestones between levels ranging from 0 to 3 (Borrmann et al., 2018; NBS, 2019) as described below.

- Level 0: This is the most basic level of BIM and involves the use of 2D CAD drawings. There is no 3D Modelling or information sharing.

- Level 1: This level adds 3D modelling to the process, but the information is still not fully coordinated. There is some use of proprietary formats and file-based collaboration.
- Level 2: This level represents the use of federated BIMs, which are multiple 3D models that are linked together. There is a greater use of open standards and central management of files.
- Level 3: This level represents the use of integrated BIM, which is a single, work-shared 3D model that is used by all stakeholders. There is a comprehensive use of IDM, IFC, and IFD standards, as well as cloud-based model management.

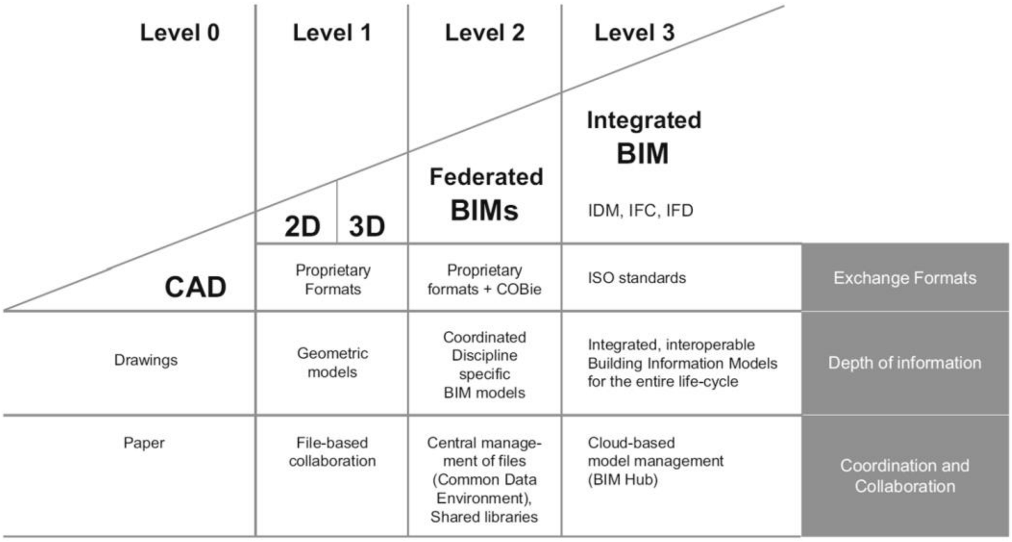

Figure 2.3: The BIM Maturity Ramp of the UK BIM Task Group (Borrmann et al., 2018)

2.1.4 Emerging Technologies and Processes Related to BIM Concepts

BIM constitutes a pivotal facet of the ongoing digitisation of the construction industry and aligns seamlessly with the overarching framework of Industry 5.0 (Wang et al., 2022; Zaed, Chen and Branka, 2023). BIM is a digitised representation of physical building structures or infrastructure assets, serving as a dynamic tool to enhance various facets of asset lifecycle management, incorporating design, construction, operation, and maintenance. The following BIM oriented descriptions are about some of emerging technologies and processes that are being used in conjunction with BIM, and these include Industry 5.0, Artificial Intelligence (AI), Digital Twins, Augmented reality (AR) and Virtual Reality (VR), Internet of Things (IoT), Blockchain (Smart Contracts), and Big Data.

Industry 5.0

Industry 5.0 is the fifth industrial revolution, which is characterised by the convergence of physical and digital technologies, the use of data and intelligence to improve decision-making and the focus on sustainability. BIM is a key enabler of Industry 5.0 in the construction industry, as BIM is a digital representation of a building or infrastructure asset that can be used to improve the design, construction, operation, and maintenance of these assets (Wang et al., 2022).

Artificial Intelligence (AI)

AI technologies, such as machine learning and natural language processing, can enhance BIM processes. AI can automate tasks like clash detection, optimise building designs based on historical data, and predict maintenance needs. Additionally, AI-powered chatbots can facilitate communication between stakeholders and the BIM model, enabling faster issue resolution and collaboration (Bassir et al., 2023).

Digital Twins

A digital twin is a virtual representation of a physical asset (Borrmann et al., 2018). BIM models can be used to create digital twins of buildings and infrastructure, which can then be used to simulate the performance of these assets under different conditions. This information can be used to improve the design and operation of these assets and to reduce the risk of problems (Wang et al., 2022; Zaed, Chen and Branka, 2023).

Augmented reality (AR) and Virtual Reality (VR)

AR and VR can be used to overlay digital information on the physical world. AR is a technology that overlays digital data, such as images, videos, or 3D models, onto the real-world using devices like smartphones, tablets, or AR glasses. It enhances the real world by adding interactive and informative digital content (Wong et al., 2020).

VR involves creating a fully digital environment that immerses users through specialised VR headsets. It transports users to simulated worlds where they can interact with and explore these environments as if they were physically present (Wang et al., 2018, 2022). The integration of BIM with AR and VR enhances the capabilities of the AECO sectors by providing more immersive, interactive, and informative experiences for all stakeholders involved in the design, construction, and operation of built assets. It can lead to better communication, improved decision-making, and more efficient and successful projects.

Internet of Things (IoT)

IoT involves connecting various physical devices and objects to the internet, enabling them to collect and exchange data. In BIM, IoT devices can be incorporated into building systems and equipment to provide real-time data on performance, maintenance needs, and energy consumption (Bilal et al., 2016). This data can then be integrated into the BIM model, allowing for more accurate predictions and informed decision-making during the design, construction, and operational phases.

Blockchain (Smart Contracts)

Blockchain is a distributed ledger technology that can be used to record transactions securely and transparently. Smart contracts are self-executing contracts that are stored on the blockchain. These technologies can be used in the construction industry to improve collaboration, transparency, and efficiency. Integrating blockchain and smart contracts with BIM can create a comprehensive ecosystem that enhances collaboration, reduces errors, and improves the overall construction and management process (Celik, Petri and Barati, 2023).

Big Data

BIM generates a vast amount of data throughout a project's lifecycle. Big Data analytics can help extract valuable insights from this data, enabling better decision-making and optimization (Bilal et al., 2016). By analysing historical project data, performance metrics, and other relevant information, construction professionals can identify trends, predict potential issues, and improve project outcomes.

2.2 BIM Implementation in the AECO Sectors

BIM has recently become increasingly recognised by AECO professionals as a tool offering a solution to productivity issues and the AECO sectors' fragmentation (NBS Research, 2018; Moreno et al., 2019). This recognition holds for both developed and developing countries. The current status of BIM in developed and developing countries in terms of its awareness, adoption, the use of digital technology, and training and education is various, and it has been identified based on analysing industry documents and national BIM reports, including those by McGraw-Hill (2012); Masterspec, (2013); National Building Specification (NBS, 2019); National Federation of Builders (NFB, 2018); BIM Acceleration Committee (BAC, 2019).

To address the growing demands of BIM implementation, the National Building Specification (NBS) introduced the Periodic Table of BIM in 2016 (NBS. 2016). This strategic roadmap, organized into 10 task groups, guides practitioners through a step-by-step process from defining BIM strategy to project handover. The technical domains and elements included in the Periodic Table of BIM are summarized below:

- Strategy: Sets overarching goals, aligns BIM with organizational objectives, and establishes a roadmap.
- Foundations: Emphasises data integrity, model accuracy, and adherence to project standards.
- Collaboration: Encourages interdisciplinary teamwork, breaking down silos for seamless information sharing.
- Process: Defines systematic approaches to creating, managing, and utilizing information in projects.
- People: Focuses on the importance of skills, knowledge, and a collaborative culture for BIM success.

- Technology: Encompasses tools and software applications facilitating BIM processes.
- Standards: Provides a common language and protocols for information exchange, ensuring consistency.
- Enabling Tools: Specific software applications and technologies supporting BIM processes.
- Resources: Involves financial, human, and technological resources required for successful BIM implementation.
- Digital Plan of Work: A component specifying the digital processes and workflows within BIM implementation.

Developed countries have been at the forefront of adopting and implementing BIM practices. BIM has been viewed as a sophisticated methodology that leverages digital descriptions of various building objects and their relationships with precision in developed countries. This enables stakeholders to simulate and evaluate building designs, construction activities, and their impact throughout the project lifecycle. BIM provides a comprehensive platform for collaboration, coordination, and data-driven decision-making. The adoption of BIM in developed countries such as the United States, Canada, the United Kingdom and Australia has been driven by the need to improve productivity, enhance project outcomes, and address industry fragmentation.

The advantages of using BIM drive the increasing recognition and integration of BIM practices in developed countries. Where, there is high awareness among industry professionals and students, leading to the widespread adoption of BIM practices. For example, in the UK, an annual survey conducted by the National Building Specification (NBS) found that the percentage of BIM adoption across all AECO sectors in the UK increased in 2011 from 58% to 79%, subsequently reaching 93% in 2013; 95% in 2014; 96% in 2015 and 2016; 97% in 2017; 99% in 2018; and 98% in 2019 (Chen et al., 2020). In addition, RIBA (2012) highlighted that architects play a pivotal role in ensuring the AECO sectors respond to opportunities offered by BIM in both the public and private sectors. RIBA has updated its Plan of Work (2013) by launching a new Plan of Work (2020), forming a crucial aspect of the new guidance to architects and co-professionals (RIBA, 2012 and 2020). BIM is a critical tool, being a new and efficient working method, due to its responsiveness and adaptability to a wide range of advanced computer programmes.

On the other hand, developing countries such as Brazil, Nigeria, Egypt, South Africa, Libya, and Saudi Arabia have also witnessed progress in BIM implementation (Amer, 2016; Karim and Nagy. 2020; Elghdban et al., 2023). These nations are experiencing increased awareness among professionals and students, resulting in the growing adoption of BIM in significant construction projects. While the use of advanced digital technologies and BIM software is not as widespread as in developed countries, there is a noticeable trend towards utilizing BIM for design coordination, project management, and construction documentation (Babatunde et al., 2021). Training programs and courses are being established within architectural education to enhance BIM skills (Labib and Nagy 2020). However, developing countries face limited awareness in certain areas, fragmented industries, inadequate infrastructure, skills shortages, and resistance to change.

The status of BIM varies between developed and developing countries, but there is a growing recognition and adoption worldwide. Developed nations have high awareness and widespread adoption, leveraging advanced technology and offering comprehensive training programs. Developing countries are catching up, incorporating BIM into significant projects, and establishing training programs.

2.2.1 Challenges of BIM Implementation in the AECO Sectors

AECO firms tend to adopt BIM for the benefits it provides to all stakeholders of a construction project, including (1) the graphic ability of the 3D model, (2) clash detection, (3) visualisation, (4) simulation, and (5) improved communication and collaboration (NATSPEC, 2019; NBS, 2019; RIBA, 2017; Georgiadou, 2019; Han and Lin, 2019). However, issues related to implementation have led to its adoption remaining slow in developed and developing countries (Enshassi et al., 2018), i.e. limited knowledge, technological challenges, resistance to change and a lack of appropriate processes (Azhar, 2011; Liu et al., 2015). The survey was conducted by BIM Africa, which aimed to identify the current status of using digital technology in the African AECO sectors. It found that BIM adoption across Africa is at a slow pace (Saka et al., 2020). The report has further identified the most critical barriers to the implementation of BIM in Africa, which are (1) lack of training, (2) lack of in-house expertise, (3) lack of government support, and (4) cost of application and training (Saka et al., 2020). However, while some hindrances are simple to remove, others can prove more problematic (Enshassi et al., 2016) by analysing industry documents and national BIM reports, including McGraw-Hill (2012); Masterspec, 2013; National Building Specification (NBS, 2019); National Federation of Builders (NFB, 2018); BIM Acceleration Committee (BAC, 2019), implementing BIM in AECO sectors comes with several challenges that need to be addressed for successful adoption and implementation. These challenges can arise in developed and developing countries and have implications for BIM implementation. The following points discuss some common challenges encountered during BIM implementation.

- Lack of standardization: One of the primary challenges is the lack of standardization in BIM practices and protocols (NBS, 2019; BIM Saka et al., 2020). Different regions, organizations, and stakeholders often have diverse regulations, standards, and guidelines, leading to fragmentation and inconsistency in BIM implementation. This lack of uniformity challenges interoperability, data exchange, and collaboration between project teams (Saka et al., 2020).
- High initial costs: Implementing BIM requires significant upfront investment in software, hardware, and training (Babatunde et al., 2021; Solla et al., 2023). Developed countries may have more financial resources at their disposal, making it easier to bear these costs. However, developing countries often face limited financial resources and budget constraints that can hinder BIM adoption (Babatunde et al., 2021). Accessing the necessary funds for software licenses, hardware

upgrades, and comprehensive training programs becomes a significant challenge (Solla et al., 2023).

- Technological infrastructure: BIM relies heavily on strong technological infrastructure and high-speed internet connectivity to handle large data sets and facilitate real-time collaboration (Enshassi et al., 2016; Saka et al., 2020). Developed countries generally have better technological infrastructure, making it easier to implement BIM. In contrast, developing countries may face challenges due to inadequate internet access, outdated hardware, and limited availability of resources for implementing advanced technologies (Saka et al., 2020; Elghdban et al., 2023).
- Skilled workforce: A critical factor for successful BIM implementation is a workforce equipped with the necessary expertise (Baldauf et al., 2020; Shojaei et al., 2022). This expertise encompasses proficiency in BIM software tools, project management methodologies tailored to BIM workflows, and strong interdisciplinary collaboration skills (Wu et al., 2014). Developed countries often have an advantage due to their established education and training programs offering comprehensive BIM courses and certifications. This creates a readily available pool of skilled professionals. However, developing countries may face a significant challenge due to a scarcity of BIM expertise, including BIM managers, modellers, and project coordinators (Sinoh et al., 2020). This lack of skilled personnel can be a major obstacle to successful BIM adoption.
- Education and training: To effectively implement BIM, it is crucial to have a knowledgeable workforce. However, there may be a lack of awareness and proficiency in BIM concepts and practices in developed and developing countries (Saka et al., 2020). Establishing educational programs, training initiatives, and capacity-building efforts become necessary to bridge the knowledge gap and equip professionals with the required BIM skills.
- Cultural resistance: The AECO sector is known for its traditional practices and resistance to change (Succar et al., 2013). Adopting BIM requires a cultural shift in the industry, which can be met with resistance. Professionals may be reluctant to embrace new technologies, workflows, and collaborative practices, hindering the widespread adoption of BIM (Borrmann et al., 2018).
- Data exchange and collaboration: BIM relies on seamless data exchange and collaboration between project stakeholders (Boton and Forgues, 2018; Saka et al., 2020). However, different software platforms, data formats, and interoperability issues can hinder efficient data sharing and coordination (Boton and Forgues, 2018; NBS, 2018, 2019; Saka et al., 2020). The lack of standardized protocols and interoperability standards poses challenges in integrating BIM models and exchanging information accurately and effectively (NBS, 2018, 2019).

Effective adoption of BIM demands a high level (therefore incurring a high cost) of education and training (Ahmed, 2018), particularly as the correct skill sets enable a company to hire (or retrain) appropriate personnel to promote the effectiveness of integrating BIM technology into its activities (Liu et al., 2015). The Royal Institution of Chartered Surveyors (RICS, 2015) has highlighted the impact of the lack of education and training on implementing BIM. The availability of training institutions can also enable companies to retrain existing staff in adopting BIM, resulting in paradigm shifts in thinking and behaviour to support the organisational changes required to integrate BIM technology and processes within an organisation's business model (Mcdonald and Donohoe, 2013). Several previous studies have indicated that high-quality education in BIM can greatly promote students' competitiveness in the current job market (Abbas et al., 2016; Zhang et al., 2022). BIM education has, therefore, stimulated significant evolution in adopting and using BIM (Smith, 2014), providing a solution capable of speeding up its learning curve.

The above challenges for the implementation of BIM in construction and architecture firms have been reported in previous studies (including case studies) in both developed and developing countries. However, BIM continues to be considered beneficial for architectural firms. In developed countries, there have been several successful examples of such implementation. In the UK, for example, the industry has acknowledged that BIM has assisted in operating built assets, decreasing building costs while also helping to decrease project duration (NBS, 2019). By contrast, a number of developing countries, including Libya, continue to encounter obstructions preventing the effective execution of BIM. Construction stakeholders in Libya have sought to use BIM during the post-recovery period (Amer and Binhanafi, 2016), with the most significant challenges for its implementation in the AECO sectors being identified as the absence of the relevant education and workforce, along with an awareness of the resulting benefits (Saleh, 2015; Saka and Chan, 2019). This skill gap has hindered the effective execution of BIM, indicating a need to find a roadmap enabling Libyan architectural companies to cover shortages in the workforce, which can be accomplished by the integration of BIM into architectural programmes to equip architectural students with the knowledge, skills, and capabilities required for its implementation.

2.2.2 The Need for BIM Education in AECO Sectors

The integration of BIM into AECO practice has become increasingly important in recent years. BIM is a digital process that allows architects, engineers, and construction professionals to collaborate and work together more effectively, creating more efficient and cost-effective building projects. For architects to use BIM effectively in their practice, it is necessary for them to have a strong understanding of the technology and the processes involved. BIM education can help architects to develop these skills and to understand how to use BIM to improve their practice. Therefore, BIM education is an essential aspect of learning the use of BIM, consisting of a training programme within an architectural firm (Scott, 2016; Budayan and Arayici, 2021), which is now offered by several practices (NBS, 2019). Training can be provided in the workplace or by specialised training organisations. It is typically technical and focuses on improving essential skills for utilising the broad scope of BIM workflows and methods (AIA-CA, 2012). However, training also needs to concentrate on the requirements of different disciplines and ways of improving project collaboration using BIM tools (Budayan and Arayici, 2021). There are several key benefits of BIM education for architectural practice, including:

- Adoption of advanced tools: BIM education introduces architects to cutting-edge software tools specifically designed for creating, managing, and analysing building information (Le et al., 2019). These tools empower architects to work in a digital environment and leverage features such as parametric modelling, data visualization, and real-time collaboration (Puolitaival and Forsythe, 2016).
- Improved collaboration: BIM allows for improved collaboration between architects, engineers, and construction professionals, enabling them to work together more effectively and efficiently (Enshassi et al., 2016). BIM education can help architects understand how to collaborate with other project team members effectively (Olowa et al., 2020; Maharika et al., 2020).
- Increased efficiency: BIM enables architects to work more efficiently by allowing them to automate many of the manual processes involved in building design (Tulubas Gokuc and Arditi, 2017). BIM education can help architects to understand how to use the technology to its full potential, resulting in increased efficiency and productivity (Ismail et al., 2019).
- Improved cost management: BIM can help architects better manage project costs by identifying potential problems and potential cost savings early in the design process (Enshassi et al, 2018). BIM education can help architects to understand how to use BIM to improve project cost management (AIA-CA, 2012).
- Better project outcomes: BIM can help architects to deliver better building projects by enabling them to identify potential problems and make informed design decisions (Georgiadou, 2019). BIM education can help architects to understand how to use BIM to improve the quality and outcomes of their projects (Ismail et al., 2019).

Although some architecture firms prefer to provide their unique BIM training programme in-house (AIA-CA, 2012; Lee and Hollar, 2013), it is also essential for universities to work alongside industry requirements (Adamu and Thorpe, 2016) and offer BIM courses, particularly for those companies having insufficient funding to deliver training (Kiviniemi, 2017). Architectural students can acquire BIM competence once they have completed their studies and then begin to apply their skills in the workplace (Damek et al., 2022). However, various firms have advised of the need for qualified organisations to deliver the non-technical training of BIM to management (i.e. team managers and project managers), which is mostly available in conferences and workshops focused on the application of BIM. Although some architecture firms can deliver training to their workers (Salami and Alothman, 2022), it has been indicated that integrating BIM into architectural education programmes is a necessary step to encouraging its adoption by architectural companies.

2.3 BIM in Architectural Education

In architectural education, BIM education facilitates knowledge, skills, and abilities associated with BIM (Olugboyega and Windapo, 2019). Architectural schools have now begun to offer courses incorporating BIM into existing programmes. Hence, several universities teach BIM using various techniques (Abbas et al., 2016; Orooji and Aly, 2017; Elias, 2022). Boton et al. (2018) noted that one of the essential aspects of successfully teaching BIM is choosing an appropriate approach, along with expert knowledge and skills.

The need for BIM education has arisen due to the current high demand for the application of BIM in the AECO sectors. Students are future staff in the AECO sectors. Thus, there is a need to equip future professionals with advanced technical solutions, along with collaboration and communication skills appropriate to address the gap between educational institutions and industry requirements (Solnosky and Parfitt, 2015; Kiviniemi, 2017; Wang et al., 2020), particularly given that the AECO sectors are facing unprecedented and dynamic change, due to the proliferation of advanced technologies and increasing environmental expectations.

2.3.1 BIM Integration within Architectural Education

Architectural schools struggle to deal with existing changes to the architecture, including the proliferation of new materials and construction and assembly management styles, along with innovative software and analysis tools (Buchanan, 2012). This results in integrating BIM technology within the architectural curricula as a comparatively new initiative for university educators, highlighting the more severe challenges faced by its adoption within the industry (Abbas et al., 2016; Abdelhameed, 2018). Despite the lack of consensus concerning teaching approaches for implementing BIM into architectural programmes (Gu and Wang, 2012; Huang, 2018; Govender et al., 2019; Zamora-Polo et al., 2019), it is crucial to review and understand the global academic initiatives for its teaching.

Institutes and universities offer workshops and academic courses on BIM to equip students and professionals with the skills to use BIM effectively. This is due to BIM's widespread adoption in the architecture and construction industries (Ibrahim and Okeil, 2011; Wu and Issa, 2014). BIM education is also being integrated into undergraduate architectural programs at universities worldwide, ensuring that graduates are well-prepared for the demands of the AECO sectors (Sampaio, 2014; NATSPEC, 2019; Shibani et al., 2020). Since BIM has been introduced in the architectural curricula, it has witnessed several phases of its integration, which can be grouped into four phases:

Phase 1: Transition from CAD to BIM

During this phase, BIM was introduced into architectural schools, replacing CAD software in many cases to incorporate BIM into high-level design studios to train students in the tools facilitating the integration of different building systems (Berwald, 2008; Lee and Hollar, 2013, Vinšová and Matějovská, (2015)).

Phase 2: Standalone BIM Courses

During this phase, BIM integration into architectural programmes consisted of practicing BIM software in standalone courses, which failed to support long-term learning for students. These courses were typically offered as electives, but some schools also began to require BIM coursework for all architecture students. This course has led to considerable efforts from practitioners, researchers and educators to investigate different approaches to the integration of BIM within the core curricula, as well as investigate its implications (Barison and Santos, 2010; Clevenger et al., 2010; Lee and Hollar, 2013; Azhar et al., 2015; Shelbourn et al., 2016). Furthermore, there has also been an extensive increase in the implementation of BIM within the AECO sectors (NBS, 2019).

Phase 3: Cross-Disciplinary BIM Integration

During this phase, architectural schools integrated BIM into all architectural curricula, including design studios, technical courses, and humanities courses. This approach recognized that BIM is not just a software tool but a new way of working in the AECO sectors (Barison and Santos, 2018; Hu, 2019). However, the teaching of BIM in architectural courses frequently concentrates on design using a 3D model and visualisation.

Phase 4: BIM-Enabled Architectural Education

This phase focuses on using BIM to transform how architectural is taught and learned. This involves developing new BIM-enabled educational resources, such as interactive BIM models and virtual reality simulations, as well as using BIM to create new pedagogical approaches, such as project-based learning (Kausar et al., 2020; Karim et al., 2022; Hajirasouli et al., 2023).

BIM-enabled architectural education is still in its early stages of development, but it has the potential to revolutionize how architects are trained (Salgado, 2020). By using BIM to create more immersive and interactive learning experiences, schools can better prepare students for the challenges and opportunities of working in the BIM-enabled AECO sectors. There are many ways in which BIM is being used to enable architectural education:

- Interactive BIM models: Students can use interactive BIM models to explore different design options and visualise their design decisions' impact on the building's performance (Sanchez-Lite et al., 2022). For example, students can use a BIM model to test the energy efficiency of different window materials or simulate traffic flow through a building.
- Virtual reality simulations: Virtual reality simulations can give students a first-hand experience of working on a construction site or operating a building. For example, students can use a VR simulation to learn about the different construction stages or practice using BIM software in a real-world environment (Hajirasouli et al., 2023).

- Project-based learning: These courses allow students to work on real-world BIM projects with architects, engineers, and contractors. This type of course allows students to collaborate with professionals from different disciplines and gain experience working on real-world BIM projects (Shikder, 2022).

BIM-enabled architectural education is helping to prepare students for the future of the AECO sectors. By using BIM to create more immersive and interactive learning experiences, schools can better equip students with the skills and knowledge they need to succeed in the BIM-enabled workplace. It is important to note that compelling content can be found when BIM is taught as a technology and process, stimulating architectural students' individual skills, knowledge, abilities, and communication skills.

2.3.2 BIM Curriculum Development

BIM curriculum development refers to the process of enhancing AECO departments' existing curricula development. Curriculum development involves the use of a variety of strategies, procedures and tools. The practice of integrating BIM within AECO departments has shown that it can be a more complicated 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 practical learning, teaching, and evaluation techniques, (4) development of a syllabus application and appraisal committee, and (5) review of the curriculum (Badrinath et al., 2016). These stages can be followed when developing a BIM-integrated curriculum.

Besides BIM curriculum design, many academics have examined how BIM is integrated within AECO programs and curricula. Joannides (2012) states that most architectural schools have incorporated BIM into their curricula and associated construction modules. In their study, however, only 4D and 5D BIM models were used in most construction schools to teach scheduling and cost estimation. Bozoglu (2016) investigated the incorporation of educational innovations such as multidisciplinary collaboration, industry partnerships, and online learning into AECO BIM programs. Their analysis revealed that most AECO programs use BIM to instruct visualization and constructability activities. These are two areas in which programs must improve their BIM utilization. Barison and Santos (2018) conducted a comprehensive literature review to evaluate existing techniques for developing BIM curriculum programs, describing the design, delivery, and evaluation of specific BIM courses. In addition, they highlighted the challenges associated with supporting BIM education and offered alternative approaches for incorporating BIM into the curriculum. The study revealed that BIM has the potential to become an integral part of the AECO industry's disciplines; therefore, when designing and implementing BIM curriculum, a number of considerations, including prerequisites, objectives, aims, content, assessments, and instructional methods, must be taken into account (Boshrabadi et al., 2021).

Architecture students must develop a global perspective on addressing the visual, technological, functional, and aesthetic aspects of inhabited spaces within the parameters of ecological contexts. A variety of course types, such as BIM stand-alone courses, design studio courses, cross-curriculum teaching modules, engineering graphics courses, and integration with existing courses, have been developed to incorporate BIM into architectural curricula (Barison and Santos, 2011). However, providing standalone BIM courses without appropriate follow-up undermines students' long-term subject retention because BIM software cannot be reused across multiple sessions. Additionally, students typically do not continue to utilize software skills after completing a single course, and standalone courses may fail because the students' AECO classes provide a different learning environment (Clevenger et al., 2010; Abdirad and Dossick, 2016).

Readjusting existing modules may also have disadvantages since current courses cover a broad range of subjects, leaving instructors 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 additional cognitive burden on instructors and students, emphasizing the learning curve of computer commands and skills more than on fundamental architectural topics (Abdirad and Dossick, 2021). In addition, students enrolled in a cost estimation course believed their knowledge of BIM contributed significantly to their overall educational experiences. On the other hand, those lacking BIM skills reported difficulty utilizing BIM tools (Sacks and Pikas, 2013). Despite these obstacles, BIM courses have been deemed beneficial, especially in the absence of an alternative method.

Numerous studies have proposed various strategies for overcoming the limitations of independent courses and integrating BIM into the current curriculum of introductory BIM architecture courses. One strategy combines these two approaches (Clevenger et al., 2010), enabling students to acquire fundamental BIM concepts and skills while providing them with advanced BIM skills and knowledge through modernized modules of current themes. Moreover, this allows students to utilize their BIM knowledge in the culminating course (Abdirad and Dossick, 2016). However, this approach faces significant obstacles, such as requirements for maintaining accreditation status and the inability of architectural programmes to adapt their curricula to market changes. Additionally, substantial prerequisites and upgrades (i.e. software/hardware and classroom equipment) are required to incorporate BIM into architectural courses, as well as the necessary technical support, logistical support, and maintenance (Sacks and Pikas, 2013; Nawari and Alsaffar, 2016).

A multidisciplinary approach to teaching BIM involves bringing students from various disciplines to reframe challenges beyond conventional limitations and develop solutions that pertain to actual AECO projects, procedures, and current issues (Badrinath, 2016). In this approach, universities must adjust BIM curricula for their students so that they can comprehend the fundamental concepts and appropriate application of BIM and study in an environment where cooperation is not merely encouraged but ingrained in the learning culture. When appropriately qualified students enter the workforce with the ability to communicate and share BIM skills with colleagues, this can be instrumental in the subsequent diffusion of BIM into industrial practice.

Many universities have implemented BIM in the design studio to introduce students to BIM technologies, with an emphasis on collaboration within and across AECO disciplines (Ibrahim and Okeil, 2011; Hu, 2019). It is common practice for architectural departments to merge BIM into the design studio, as it enables the ability to plan, control, and coordinate the entire project from beginning to end (unlike conventional operations) (Barison and Santos, 2010a). This exposes students to new problems encountered in a comprehensive design studio (Abdirad and Dossick, 2016), thereby facilitating the development of the required breadth of knowledge and skills. Several BIM academic initiatives have focused on developing BIM curricula and implementing various methodologies in a variety of AECO disciplines, such as construction engineering and management. However, comparable efforts are lacking in some critical AECO areas (e.g. architectural and civil engineering), which require additional research to address the lack of BIM-integrated curriculum development in architectural education.

In summary, the review revealed that a number of BIM academic initiatives aim to develop BIM curricula and implement different methods in various AECO disciplines, such as architecture, construction engineering, and management. However, the current state of BIM education demonstrates that the BIM curriculum in undergraduate architectural education does not meet the minimum requirements for professional practice. On a more positive note, developing an inclusive curriculum for human resource education that meets industry and academic needs is essential. The following points should be followed in the process of developing the BIM curriculum:

- Define clear learning outcomes aligned with BIM integration goals.
- Develop courses that progress from foundational to advanced BIM concepts and tools.
- Foster interdisciplinary collaboration and incorporate projects with other disciplines.
- Provide practical experience through hands-on exercises, projects, and internships.
- Engage with industry professionals and align curriculum with industry practices.
- Support faculty development in BIM expertise through training and resources.
- Use appropriate assessment methods to evaluate BIM knowledge and skills.
- Gather feedback to improve the curriculum and address emerging trends continuously.

2.3.3 BIM Course Implementations

Course designers worldwide have used a variety of pedagogical approaches to ensure that students understand all BIM concepts and processes covered within BIM courses. Lee et al. (2019) made substantial contributions to the curriculum of construction engineering education by creating a BIM course with a systematic three-stage development strategy (preparation, development, and improvement). This course outlined the educational goals and objectives, learning subjects, composition of learning subjects, and evaluation methods associated with BIM education for construction management education in Korai. Tsai (2019) taught BIM with a peer-review approach, including guidelines for the instructor on how to design a course for the students to study and assess their work. The results of this course demonstrated that students gained more specific knowledge and skills related to 3D BIM modelling and gained insight from the works of others.

After analysing various case studies, (Sacks and Pikas, 2013) made some recommendations for BIM education, which underlined the need for the continuity of BIM education and the educational advantages of BIM visualization and simulation, noting that students think that pairing BIM courses with real-world examples may assist them better understand BIM applications. Forsythe et al. (2013) described a program-wide application plan for a BIM-supported teaching development programme at the University of Technology Sydney (UTS) and emphasised 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 a number of countries have prioritized BIM education. Universities have made numerous attempts to establish BIM curricula, and educationalists intend to develop suitable curricula and BIM specialists. Kaunas University of Technology (KTU) and Vilnius Gediminas Technical University (VGTU) offer undergraduate and postgraduate BIM courses (respectively). The objectives of the master's degree programme at KTU are to instruct professionals and design and develop criteria that will govern and organize BIM drafting (Jolanta and Pupeikis, 2018). At Helsinki Metropolia University of Applied Sciences, the "OpeBIM" initiative modifies curricula and courses to integrate BIM into current courses in order to facilitate interdisciplinary collaborative learning. In addition, to address the development of local industrial resources related to BIM practices, the University of Auckland offers BIM courses to undergraduate and graduate students and actively participates in New Zealand's national BIM education design, implementing various BIM-related courses in national institutions in a gradual manner (Suwal et al., 2013).

As outlined above, several BIM researchers and educators have already conducted experiments with academic BIM education courses in a range of AECO disciplines employing various approaches. In addition to courses designed to advance BIM knowledge and practice, some courses have sought to promote awareness and skills in relation to specific aspects of AECO sector activity, such as sustainability. Lewis et al. (2015) proposed a system for BIM energy modelling based on the Revit tools-based energy modelling training module, which was designed and implemented to familiarize architecture and engineering students with the energy modelling process.

Numerous innovative teaching strategies and concepts (such as open resources, sustainability, professor-student collaboration, industry-academia partnerships, and project-based learning) have been developed and implemented in AECO department BIM courses. The work and experiences of these global BIM researchers have produced a vast knowledge base that other BIM educators and researchers from different parts of the world can utilize. Furthermore, these BIM experimental experiences in AECO department courses can be utilized to develop a practical BIM curriculum, thereby advancing academic BIM education.

2.3.4 BIM Competencies for Architectural Students

The integration of BIM education into AECO programs has encountered several challenges, including identifying the appropriate competency or body of knowledge for architecture students to meet future employment expectations. “Competence” is a phrase that has been widely used in the AECO sectors to encompass a variety of elements, including knowledge, abilities, and behaviours. An excellent architectural syllabus must strike a balance between these BIM principles. Existing BIM competence indexes are directed at BIM as professionals use rather than at the unique requirements of architects and architecture students (Succar, 2009).

To help architecture students acquire BIM competencies, it is essential to understand the BIM process in design projects. Barison and Santos (2011, 2012) examined how AECO firms implement BIM workflows to determine the BIM skills required of architects. In actual projects, architects start by developing a concept model, which is then sent to the BIM project manager, who analyses the information needed to be included before forwarding it to another BIM model manager. Architects must collaborate with contractors and specialists to determine the most suitable technology, building details, and construction. This requires not only BIM knowledge but also crucial cooperation and communication skills.

Typically, architectural education considers the teaching of basic nonverbal (graphic) communication skills and the use of computers and other technologies required to develop an efficient and cost-effective architectural project. Additional skills taught include research, cognition (analytical and critical thinking), interpersonal relationships (teamwork), and graphs, tables, and formulas interpretation. Architecture students gain knowledge of architectural design, architectural drawings, and material components. In addition, they must be familiar with other fundamental disciplines (such as structure and energy) and learn lean building processes and procedures. However, undergraduate architecture courses are not long enough to adequately prepare students to serve as project managers.

Due to the distinctive nature of the architectural syllabus, students should acquire a broad range of skills and knowledge in numerous disciplines and methods (Bozoglu, 2016). This allows them to oversee an entire structure's location and operation. Because of the complexity of AECO professions, ICT is required for defining the most qualified candidate for a BIM environment. Incorporating BIM into an architectural programme requires focusing on specific competencies related to BIM and its tools used in practice. Coates, 2018; and Hossain and Zaman (2022) suggest including the following essential BIM competencies for undergraduate architectural students: 3D modelling, coordination, collaboration, data management, visualization, energy analysis, project management, and quantity take-off. **Table 2.1** provides an overview of crucial BIM competencies, with their associated learning objectives and commonly used tools in the field.

Table 2.1: BIM competencies and tools used in architectural academics and practice.

BIM Competency	Learning Objectives	BIM Tools
3D Modelling	- Create and modify parametric models. - Understand object properties and relationships. - Develop detailed 3D models for visualization and analysis.	- Autodesk Revit - ArchiCAD - SketchUp
Coordination	- Perform clash detection and resolution. - Coordinate multidisciplinary models.	- Navisworks
Collaboration	- Collaborate with project team members. - Manage and track design changes.	- Autodesk BIM 360
Data Management	- Organize and manage project data and information. - Establish and maintain data standards.	- Autodesk Revit - Autodesk AutoCAD
Visualization	- Create visual presentations and renderings. - Generate 3D walkthroughs and virtual reality experiences.	- Lumion - Enscape
Energy Analysis	- Perform energy simulations and analysis. - Optimize building energy performance.	- Autodesk Ecotect
Project Management	- Use BIM tools for project scheduling and sequencing. - Track project progress and monitor performance.	- Autodesk Revit - Microsoft Project
Quantity Take-off	- Extract quantities and measurements from BIM models. - Generate accurate cost estimates.	- Autodesk Revit - CostX

According to the reviewed studies, the introduction of BIM education into architectural programs has been impeded by the ongoing difficulty of providing students with the entire Body of Knowledge (BOK) necessary for architectural education per se and professional competence as an architectural professional in actual industrial practice. In other words, there is a lack of systematic understanding and the establishment of fundamental knowledge, skills, and capabilities to successfully implement BIM within the architectural programme to fulfil the requirements of architectural students and the AECO sectors. The society of BIM educationalists, practitioners, and service users' needs a BIM Body of Knowledge (BIMBOK), which can be defined as the entire collection of activities, principles, values, terms, concepts, competencies, and outcomes that comprise a professional field.

2.3.5 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, centred on whether BIM concepts should be introduced at the lower or upper levels of education programs. According to (Boton et al. (2018), an excellent implementation strategy should be iterative to gradually increase community awareness, identify best practices, and learn from mistakes. Thus, BIM should initially be introduced within a current topic before being applied to other issues, either as a specific course or as a component of another subject (Hietanen and Drogemuller, 2008; Barison and Santos, 2010). The overall structure consists of transitioning from a single individual to a team or group that employs collaboration. Students should practice on an actual project with a suitably qualified firm during their final year (Kymmell, 2008; Barison and Santos, 2010; Manish, 2013).

An effective strategy for incorporating BIM into Brazilian architecture and civil engineering programs underlines numerous methods for teaching BIM throughout the curriculum and at all levels of education. **Table 2.2** explains how the framework was developed based on three levels: introductory, intermediate, and advanced. The introductory level emphasizes the development of BIM modeller and facilitator skills, while the intermediate level focuses on BIM analyst activities that complement BIM designer skills. This level corresponds to that of a BIM manager or coordinator. In addition, the framework suggested six distinct course types for teaching BIM at each level: standalone course and digital graphic representation (introductory level); building technology and integrated design studio (intermediate level); and construction management and interdisciplinary design studio (advanced level) (Barison and Santos, 2012).

Table 2.2: BIM teaching and learning strategies.

Level	**Introductory Level**	**Intermediate Level**	**Advanced Level**
Skills	BIM modeller	BIM analyst	BIM manger and coordinator
Prerequisite	- CAD skills are not required. - BIM concepts - A common BIM tool	- BIM concepts - Building materials - Design fundamentals - BIM modelling tools	- Construction methods - Professional practices - Building Technology - BIM modelling tools
Course	- Standalone course - Digital Graphic representation	- Building Technology - Integrated Design Studio	- Construction Management - Interdisciplinary Design Studio
Application	- A small building project with a size of or less 6oo m^2.	- A small modern building with a size of or less 1000 to 5000 m^2.	- An actual project with a more complex structure with a size of or less than 5000 to 15000 m^2.
Evaluation methods	- Independent exercises - Written examination - A presentation about BIM concepts	- Submitted files in original format. - Integrated tools - Verify the process applied in modelling. - Evaluation lessons learned	- verbal and visual presentation - Case studies - Participation in classroom - Integration in team - level of information incorporated. - Technical visits reports

While the framework of (Barison and Santos, 2012) is an excellent starting point for attempting to teach BIM, it lacks appropriate depth for each level, resulting in inadequate course material comprehension. Another disadvantage of this framework is its reliance on a single teaching method (project-based learning) for all levels, which does not meet the needs of different courses and (pedagogically) learners. This pertains to the question of how to correlate BIM learning outcomes with academic levels. The BAF framework divided BIM learning objectives into three categories: (1) knowledge and understanding, (2) practical skills, and (3) transferable skills. Moreover, these categories are linked to the academic standards for undergraduate English levels 4 to 6 in the UK. These programs are utilized by construction, engineering, and architecture professionals and students (BAF, 2013). Nonetheless, expertise is absent at each level. It is essential to identify the necessary learning outcomes associated with BIM/digital construction practical skills, knowledge, and information. Learning should take place at a rate that is suitable for the individual student.

In summary, the identification of academic-level content should strike a balance between traditional knowledge and the BIM learning curve. Universities are encouraged to select the appropriate undergraduate level at which to begin embedding BIM based on the needs of learners and competency, pedagogical considerations, and university facilitation and capacity issues. However, it is preferable to introduce BIM at the undergraduate level as opposed to the graduate level because students will strengthen their BIM skills and knowledge through projects and training under the supervision of academic tutors, gaining more support and guidance throughout their academic journeys. After completing this academic level, students can work on real projects without difficulty. Integration of BIM at the graduate level is essential for the advancement of BIM research. In addition, it is recommended that the bachelor's degree provide students with the necessary knowledge and skills in BIM, including those of the BIM modeller and facilitator, BIM analyst, BIM manager, and BIM coordinator, so that graduate students are BIM experts and “think BIM.”

2.3.6 Barriers and Issues of BIM Integration with Architectural Education

The introduction of BIM into architectural education, and engineering education in general, has encountered many obstacles that impede its full implementation. It is not unusual for any emerging technology to present challenges during the development of a university programme.

The primary concerns of BIM education are staff and students, education product, and education process (Badrinath 2016; Zaed et al., 2021). Introducing a new ICT, such as BIM, requires a modern laboratory equipped with the necessary equipment to conduct successful courses. Additionally, this requires a well-specified server capable of managing the vast storage capacity of various BIM users. BIM software and hardware are frequently prohibitively expensive, and reports indicate that university educators struggle to select appropriate tools (Maina, 2018). Professional and well-trained technical support staff are also required to maintain laboratories' hardware and software configurations. Moreover, there are some issues with software licenses, interoperability, and a scarcity of intelligent BIM software that detects and corrects errors (Belayutham et al., 2018). Other issues relating to organizational capability include a lack of space for new classes; this applies to both the curriculum and the estate (Shibani et al., 2020). In addition, adequate financial support is required to develop educational infrastructure, software, hardware, and teacher training to address these issues.

A critical component of BIM education is the establishment of a link between academia and industry practices. This missing link demonstrates the current disconnect between industry expectations and academic outcomes (Damek et al., 2022). This issue must be addressed through the formation of partnerships between educators and professionals. Additionally, the BIM process necessitates construction knowledge, which many students lack (usually due to inexperience). It is beneficial for students to gain work experience and develop industry skills that enable them to apply their academic knowledge in real-world work situations.

Additionally, academics must address issues relating to the integration of BIM education policies. First, it is necessary to overcome resistance to change and the non-availability of educationalists willing to offer BIM courses (Elias, 2022). The primary impediment to the adoption of new BIM modules in academia is the requirement to develop novel teaching and learning strategies (Babatunde and Ekundayo, 2019). The lack of staff proficiency with BIM tools is a significant issue that teachers and tutors must address through ongoing professional development (Puolitaival and Forsythe, 2016). Other obstacles may exist for universities wishing to incorporate BIM. However, many of these will be institutional in nature, such as promoting BIM integration within and across disciplines and aligning with the programs of other departments. BIM education is proposed to be incorporated into the university's vision to promote BIM among faculty and students.

The key challenges faced during the process of BIM implementation and the development of curriculum can be identified as relating to establishing an effective balance between theory and practice, technology and process, and traditional and emerging methods in the AECO industry (Puolitaival and Forsythe, 2016; Boton et al., 2018; Chen et al., 2020). An interdisciplinary approach is a key to BIM learning and poses a challenge for diverse disciplines with varied education objectives, teaching schedules, expectations, and research (Nushi and Basha-Jakupi, 2017). Effective teaching of BIM thus requires a coordinated approach in terms of teachers, curriculum, students and university requirements. These factors have been commonly regarded as crucial for successful organisational change (Enegbuma et al., 2015).

2.4 Global Academic Initiatives of BIM Curriculum Development

Several BIM education frameworks employed by academia and industry have been established worldwide. However, educators still face many issues when teaching BIM, which raises the question of why some organisations and universities are unable to apply BIM education successfully. This section reviews and analyses some global initiatives development of BIM education frameworks in the United Kingdom, Australia and the United States. The choice of these developed countries for reviewing global BIM education frameworks is justified by their proactive approaches to BIM implementation, significant industry adoption, government support, and the presence of well-established academic programs and initiatives. Analysing the experiences and practices in these countries can provide valuable insights into effective strategies for BIM curriculum development and contribute to the ongoing advancement of BIM education globally.

2.4.1 Academic Initiatives in the United Kingdom

In the UK, a strategic roadmap for BIM incorporation into the curriculum for higher education certification has been established by the BIM Academic Forum (BAF), which is comprised of leading academics from UK and Irish Universities. The development of the framework was motivated by the government's mandate to use BIM on all public projects by 2016. In line with this, it was realised that there is a requirement to collaborate with educational organisations to meet current accreditation criteria.

BIM Academic Forum (BAF) has broken down the potential learning outcomes between levels four to seven of higher education (BAF, 2013). Furthermore, a professional roles/disciplines series was used to apply a filter. The objective of the academic framework is to provide a platform to include the long-term vision of BIM learning as part of the relevant undergraduate and postgraduate levels. Appropriate BIM knowledge can assist in the development of professional skills. At the same time, it is essential to establish a skill competency matrix for the different kinds of undergraduate and postgraduate discipline-specific programme levels, along with comprehensive and consistent BIM learning outcomes (BAF, 2013).

BAF divides BIM learning outcomes into three groups: firstly, knowledge and understanding; secondly, practical skills; and third, transferable skills. **Table 2.3** illustrates the learning outcomes for undergraduate levels 4-6. In the BAF report, Cracknell (2013) emphasised that initial BIM LOF should be linked to academic levels within the AECO industry by considering the three levels of need, i.e. strategic, management and technical.

Table 2.3: BAF learning outcomes at undergraduate levels 4 to 6 (BAF, 2013)

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

BAF groups academic levels according to those of the UK: firstly, an undergraduate (level 4 to 6) and secondly, a postgraduate (level 7) (BIFM, 2017). As this current research focuses on undergraduate architectural programmes, it reviews levels 4 to 6.

- Level 4: for undergraduate academics, level 4 is the first year. The objective of BIM and its association with the AECO industry must now be understood along with the technology and its use within the disciplines. The level is also referred to as the BIM conceptual knowledge.
- Level 5: the academic level in the second year is level 5. BIM knowledge is considered a high level where the students should understand the supply chain integration and construction procedures of BIM. Furthermore, they should be familiar with modelling tools and software programs of BIM to establish models and visualisation. Teamwork BIM management and sustainability knowledge are also attained at this level. BIM applied skills is another name for this level.
- Level 6: the last academic and third year is level 6. BIM learning is also considered a high level. The students at this level must manage sustainability effects, large-scale project management abilities, and BIM (IPD) project delivery. BIM technical support is another name for this project.

Such programmes are used by practitioners and students forming part of the construction, engineering and architectural sectors. The objective of the framework is to assist undergraduates in attaining the relevant knowledge and skills concerning BIM. This is limited by a lack of competency available for each specific role. In addition, extracting the requirements for learning outcomes concerning BIM/digital construction practical skills, understanding, and knowledge is necessary. Learning occurs at the relevant levels of the undergraduate and postgraduate education discipline-specific to 4 to 7 HE levels.

2.4.2 Academic Initiatives in Australia

The Sydney University of Technology has enhanced and upgraded BIM in Australia. Using BIM tools, they created a collaborative design education system amongst the AECO discipline students, which led to the recommendations for the Illustration, Manipulation, Application, and Collaboration (IMAC) Framework (MacDonald, 2013). For AECO-ES, the collaborative design was enhanced through the use of the IMAC BIM Framework while acknowledging that educators-maintained control of the benchmarks for their courses. The framework level has four stages based on several achievement levels, i.e., IMAC. Several learning taxonomy levels of Bloom are used to map the stages (MacDonald, 2013). The four stages are elaborated below:

- Illustration Stage: This is the knowledge stage for BIM technology where the students must recognise the BIM concept, building associations, and contractions of buildings. Hence, they would thoroughly comprehend the building lifecycle and influence the advanced level modelling quality.
- Manipulation Stage: it is a BIM knowledge advance level, where the students use BIM tools and applications, establish simple models, present small edits, attain discipline-specific knowledge and enhance their teamwork and basic IT literacy proficiencies.

- Application Stage: it is an advanced stage where the students are experienced in architecture science and the use of BIM tools. However, they should further learn the advanced modelling steps and recognise how interdisciplinary collaboration can be effectively managed. With BIM experts' assistance and tools, students must also be able to assess models. Construction managers should create 4D and 5D schedules and logistic and material order planning through models extracted from other disciplines. Furthermore, sustainable design and value engineering principles are to be included. They must comprehend how to integrate the BIM tools.
- Collaboration Stage: Inter-disciplinary collaborative activities are carried out for the joint project as part of this stage. Students from each AECO discipline must be included as part of the working group. They should attain further knowledge regarding contract types to enhance BIM use and collaborative work. The students must resolve real-world issues given by the teachers.

This framework does not maintain any association with academic levels. Each university has the freedom to decide whether the BIM system should be included within the curriculum based on students’ knowledge at each step (MacDonald, 2013). Due to its positive features, the framework has proved successful in Australia. However, it has not maintained any country-specific features which can be applied to other education systems. It is thus a flexible framework, capable of enhancing the whole curriculum or mapping a particular course segment.

2.4.3 Academic Initiatives in the United States

BIM education in the United States has been shaped by the industry's recognition of the transformative potential of this technology in project delivery. Numerous universities have incorporated BIM into their architecture, engineering, and construction programs. Notably, industry associations such as the American Institute of Architects (AIA) collaborate closely with educational institutions to create resources for BIM education. The National BIM Standard-United States (NBIMS-US) serves as a basic framework for implementing BIM education across diverse academic programs.

Despite these developments, a standardized national BIM education framework is currently lacking in the United States. As a result, BIM curriculum varies between universities, with each institution independently adapting its programme to include BIM technology, as highlighted by Wu and Issa, (2013). The study conducted by Becerik-Gerbeer et al., (2011) examined 101 AECO programmes in the US and found that the integration of BIM predominantly occurred from 2006 to 2009. The research also indicated that architectural schools were at the forefront of incorporating BIM courses, with construction management programs lagging. However, BIM-related topics are integrated into the curriculum of most AECO education programs, encompassing a wide range of aspects, as outlined by Becerik-Gerber et al. (2011). Furthermore, numerous educational institutions offer various BIM-focused events, including workshops and short courses. These initiatives primarily focus on providing software training and enhancing awareness of BIM applications, as noted by Wu and Issa (2013).

2.5 The Importance of Integrating BIM into Architectural Education

BIM is a digital technology that enables the creation of virtual models of buildings. BIM facilitates the simulation of construction processes, identification of potential issues, and overall efficiency improvement. As the AECO sector in developing countries is still in its early stages of development (Elghdban et al., 2023), there is a growing interest in BIM and a need to train architects and construction professionals in BIM tools. Integrating BIM into undergraduate architectural programs would equip future architects with the necessary skills to thrive in the AECO sectors. There are several benefits associated with integrating BIM education into undergraduate architectural programs for architecture students:

- Enhanced understanding of the construction process: BIM education provides students with a comprehensive understanding of the construction process, enabling them to visualize and analyse projects in a digital environment (Aljad, 2023).
- Early identification of problems: BIM allows students to identify and address potential issues during the design phase, reducing the likelihood of costly and time-consuming problems during construction (Alizadehsalehi et al., 2021).
- Improved communication within construction teams: BIM fosters better communication and collaboration among architects, engineers, contractors, and other stakeholders, leading to smoother project execution (Alizadehsalehi et al., 2021).
- Enhanced creativity and design skills: BIM tools allow students to explore innovative design solutions, pushing the boundaries of creativity and expanding their skill sets (Labib and Nagy, 2020).
- Increased competitiveness in the job market: Proficiency in BIM is increasingly valued in the construction industry. Integrating BIM education equips graduates with sought-after skills, enhancing their employability and career prospects (Elias, Issa and Wu, 2022).

In addition to the benefits for students, integrating BIM education into undergraduate architectural programs can provide advantages for universities. BIM courses can increase student enrolment by attracting more students interested in gaining expertise in this cutting-edge technology. Also, the BIM programme can be expanded research opportunities by open avenues for research collaborations, enabling universities to contribute to advancements in the field.

Besides, teaching BIM in architectural education is vital for the AECO sectors. The primary goal of architectural education is to equip future architects with the necessary skills and knowledge to contribute to the industry's digital transformation (Hossain and Bin Zaman, 2022). Architectural education can advance BIM implementation, improve project outcomes, and foster innovation in the built environment by producing a skilled workforce and reducing adoption costs.

In addition to these benefits, integrating BIM into undergraduate architectural programs can promote sustainability, improve the quality of buildings, reduce waste, and create better working environments for construction workers (Moustaka et al., 2019). By embracing BIM and integrating it into architectural education curricula, Libya can position its construction industry at the forefront of innovation and ensure its future architects possess the skills necessary to drive positive change and advancement in the field.

2.6 The Need to Restructure Architectural Education to Integrate BIM

The AECO sector is undergoing a digital transformation and BIM is at the forefront of this change. BIM is not just a software programme; it's a collaborative process that integrates design, construction, and operational data throughout a building's lifecycle. It is imperative to restructure architectural education to equip students with the knowledge, skills, and competencies required to thrive in a rapidly changing industry (Crawley, 2014: Zhang and Wu, 2018), a restructuring of architectural education to integrate BIM is essential for several reasons including:

- Industry demand: AECO sectors increasingly require BIM expertise from their employees. Graduates without BIM skills will be at a disadvantage in the job market.
- Improved collaboration: BIM fosters collaboration between architects, engineers, and constructors, leading to a more efficient and streamlined building process. Educating students in this collaborative environment prepares them for the realities of the job.
- Enhanced design and decision-making: BIM allows for data-driven design, enabling students to analyse factors such as energy efficiency and constructability early in the design process.
- Future-proofing graduates: By integrating BIM, architectural education equips students with the skills and knowledge necessary to thrive in the digital future of the architecture industry.

Restructuring architectural education does not mean leaving traditional design principles. It is about incorporating BIM as a technology and process to enhance creativity, improve communication, and optimise building performance. This successful integration hinges on addressing the following integration issues identified in the literature review:

- Curriculum design and development: Studies advocate for the holistic integration of BIM principles throughout the curriculum outcomes (Abdirad and Dossick, 2016; Coates et al., 2018; Liu et al., 2021). This means introducing BIM concepts early into core courses such as design studios, construction technology, and environmental analysis (Chen et al., 2021). While software proficiency is valuable, a shift towards understanding BIM workflows for different project stages (conceptual design, detailed drawings, construction documentation) is crucial (Lee et al., 2019). Dedicated BIM courses can explore advanced topics such as parametric modelling, BIM-based energy analysis, and collaborative tools. Collaboration with practicing architects ensures the curriculum reflects real-world BIM usage and software trends (Coates et al., 2018).

- Education infrastructure development: Investment in BIM software licenses for student use is dominant (Chihib et al., 2019; Abdirad and Dossick, 2021). Exploring student discounts or open-source options can address affordability concerns. Upgrading hardware to meet the demands of BIM software is equally important (Maina, 2018; Maharika et al., 2020). Cloud-based solutions offer flexibility and scalability. Dedicated BIM labs equipped with specialized hardware and software foster collaboration and focused learning. The potential of integrating virtual reality (VR) for immersive design review and BIM model exploration is an emerging area of interest (Wang et al., 2022).
- Professional development: Faculty development programs on BIM software and workflows are essential to equip educators for effective teaching (Isanović and Çolakoğlu, 2020). Encouraging practicing architects and BIM specialists for guest lectures exposes students to industry best practices and real-world experiences. Industry internships with a focus on BIM provide invaluable practical experience for students (Puolitaival and Forsythe, 2016).
- Academic and professional collaborations: Collaboration with architectural firms offers opportunities for students to work on real-world BIM projects, receiving industry feedback and tackling practical challenges (Silverio et al., 2016). Participation in BIM competitions foster exposure to cutting-edge BIM applications and industry standards. Establishing advisory boards with BIM professionals provides ongoing guidance for curriculum and programme development (Abdelhai, 2022).

2.6.1 Frameworks to Restructure Architectural Education by Integrate BIM

This section explores how architectural programmes can be restructured to effectively integrate BIM, drawing upon established frameworks such as the CDIO Approach, the Technological Pedagogical Content Knowledge (TPACK) Framework, the Advanced HE Framework for Education for Sustainable Development (ESD), AiC BIM BOK and the NBS Periodic Table of BIM.

2.6.1.1 Framework for Education for Sustainable Development (ESD)

The architectural profession faces a critical challenge: integrating sustainability principles into design practices to address environmental concerns. BIM offers a powerful set of tools to support this shift. However, effectively integrating BIM into architectural education requires a well-defined framework and strategic implementation. This section explores how the Advanced HE ESD Framework (Norton, 2022; Kay, 2024) can guide the restructuring of architectural curriculums for a sustainability-oriented BIM education.

Sustainable design practices are becoming increasingly crucial in the architectural field. The rising demand for environmentally responsible buildings necessitates graduates equipped with the knowledge and skills to deliver them. The ESD Framework plays a significant role in achieving this goal. Frameworks such as the ESD provide valuable guidance by emphasizing the integration of ESD principles throughout the curriculum, enhancing students' capabilities for sustainable design, and fostering transformative learning experiences (Norton, 2022; Kay, 2024).

The ESD Framework provides a structured approach for integrating BIM and ESD into architectural education. This framework utilises a four-stage process which can help when developing the BIM Excellence Framework:

- Diagnostic stage: This stage involves a thorough examination of the current curriculum, identifying gaps in BIM, and gathering stakeholder perspectives (faculty, students, industry professionals) through surveys, interviews, and curriculum reviews. This analysis helps pinpoint areas for improvement and informs the restructuring process.
- Design and development stage: Based on the diagnostic findings, the curriculum is redesigned with specific goals and objectives for BIM and ESD integration. Learning outcomes are formulated to combine BIM proficiency with a strong understanding of sustainable design principles. The curriculum may incorporate new modules or courses focused on areas such as energy modelling and life cycle assessment, allowing students to learn BIM software alongside its application in sustainable design analysis.
- Intervention and implementation stage: This stage involves putting the redesigned curriculum into action. Course syllabi are revised, new BIM-focused modules or courses are implemented, and experiential learning opportunities such as case studies and project-based learning are introduced. These real-world experiences allow students to apply their BIM skills to tackle sustainable design challenges. Additionally, faculty training on BIM pedagogy and software usage is crucial for successful implementation.
- Evaluation stage: The final stage focuses on assessing the effectiveness of the restructured curriculum. Student performance in BIM-integrated courses, their ability to utilize the software for sustainable design considerations, and their overall project work are evaluated. Feedback from faculty and students is collected through surveys and interviews. By analysing learning outcomes and comparing them with established benchmarks, institutions can identify areas for continuous improvement and ensure the curriculum effectively equips future architects with the necessary skills to design and build for a sustainable future.

2.6.1.2 CDIO Approach

The architectural profession demands graduate’s adept at BIM for efficient and sustainable design practices. Traditional pedagogical approaches often struggle to equip students with the necessary hands-on experience and industry-relevant skills. This section explores how the CDIO Framework can guide the restructuring of architectural curriculums for effective BIM integration. The CDIO approach is an innovative educational framework that emphasizes active learning, project-based experiences, and real-world applications in engineering and technical education (Crawley, 2014).

The CDIO approach's philosophy corresponds to the concept of the BIM life cycle: design, construction, and operation. Besides, the CDIO model is currently well-known and broadly used within engineering education, and its framework is easy to understand. The main goal of the CDIO project: a university graduate (an engineer) should be able to come up with a new project or a new technical idea, carry out or manage all design work for its implementation, introduce the design result into production (Zhang and Wu, 2018).

The employ of CDIO principles makes it possible to develop a comprehensive approach to training graduates in technical areas (i.e. BIM) to conduct engineering activities at all stages of the life cycle of technical and technological products. CDIO Syllabus identifies four groups of education outcomes. (1) Technical Knowledge and Reasoning; (2) Personal and Professional skills and attributes; (3) Interpersonal skills: Teamwork and Communication; (4) Conceiving, Designing, Implementing and Operating systems in the enterprise and societal context (Crawley, 2014).

BIM software offers a comprehensive suite of tools for architects to create, analyse, and optimize building designs. Integrating BIM into the curriculum is crucial for preparing future graduates to navigate the evolving architectural landscape. The CDIO approach, with its emphasis on active learning and project-based experiences, provides a valuable framework for achieving this goal.

The integration of the CDIO approach into architectural education curriculums involves rethinking traditional teaching methodologies and embracing a more experiential and student-cantered learning paradigm. The CDIO Framework utilizes a four-stage process to restructure architectural education for BIM integration:

- Conceive stage: This stage involves collaboration with industry professionals and educators to identify the core objective of BIM education. Defining programme objectives, establishing student learning goals, and identifying relevant project-based learning opportunities are key aspects of this phase. For instance, collaboration with industry partners can help identify the specific BIM competencies sought after in the workforce.
- Design stage: Based on the identified competencies, curriculum designers develop a strategic roadmap. This involves defining course sequences that progressively build BIM skills throughout the program. Integrating project-based learning activities allows students to apply BIM software in real-world scenarios, such as designing sustainable buildings or collaborating on virtual construction simulations. Additionally, aligning curriculum components with the latest BIM software advancements and industry trends ensures graduates possess the most relevant skillsets.

- Implement stage: This stage focuses on putting the redesigned curriculum into action. Courses are modified to incorporate hands-on BIM labs, project-based learning activities, and industry collaborations. Educators facilitate active learning experiences by encouraging students to explore BIM software functionalities and utilise them throughout the design process. Furthermore, opportunities for interdisciplinary collaboration, such as working with engineering students on BIM-based structural analysis, can be fostered.
- Operate stage: Ongoing assessment and improvement are critical aspects of the CDIO approach. Feedback from students, industry partners, and faculty is used to evaluate the effectiveness of BIM integration in achieving learning outcomes. Regular curriculum reviews and adaptation ensure students are equipped with the most up-to-date BIM skills and knowledge required for success in the architectural workforce.

2.6.1.3 The Technological Pedagogical Content Knowledge (TPACK) framework

TPACK Framework developed by Mishra and Koehler (2006), offers a valuable structure for designing effective curricula that integrates technology. It emphasizes the interplay between three core knowledge domains:

- Content Knowledge (CK): Understanding of the subject matter that is to be taught or learned.
- Pedagogical Knowledge (PK): Understanding of the methods and processes of teaching and learning, including educational purposes, values, and aims.
- Technological Knowledge (TK): Knowledge of the use and application of technology tools and resources.

The TPACK framework goes beyond these individual domains by highlighting the importance of:

- Technological Content Knowledge (TCK): Knowledge of how technology can create new representations for specific content.
- Technological Pedagogical Knowledge (TPK): Knowledge of how teaching and learning can change when particular technologies are used.
- Pedagogical Content Knowledge (PCK): Knowledge of how to teach specific content effectively.

In architectural education, TPACK can guide the integration of BIM by ensuring that technological tools (e.g., BIM software) are effectively aligned with pedagogical approaches and architectural content. For instance, Thohir et al. (2023) emphasize that TPACK Framework supports educators in designing curricula that incorporate BIM technologies to enhance students' understanding of architectural principles and design processes. Hjelseth (2015) argue that BIM-based teaching methods can be related to TPACK in the following ways:

- Information Delivery Manual: This aligns with Pedagogical Content Knowledge (PCK), as educators must effectively convey architectural content within the BIM context. As suggested by Elghdban et al. (2023) utilizing interactive BIM models can enhance students' comprehension of complex spatial relationships.
- BIM-based Model Checking: Related to Technological Content Knowledge (TCK), this aspect requires educators to understand the capabilities of BIM software for quality control and error detection. Bassir et al. (2023) found that integrating BIM clash detection exercises improved students' attention to detail and problem-solving skills.
- BIM Execution Plan: Aligning with Technological Pedagogical Knowledge (TPK), this involves effectively using BIM to facilitate collaboration and communication. According to Hajirasouli et al. (2023), incorporating virtual team-based projects with BIM can foster effective communication and teamwork among students.

Hjelseth (2017) explores the use of TPACK frameworks to enable the systematic implementation of BIM in higher education in order to create BIM curricula that move beyond basic software training. This can be done in the following way as suggests by Hjelseth (2017):

- Technological Knowledge (TK) Development: Include modules on core BIM software functionalities (e.g., modelling, collaboration tools) ensuring students gain proficiency.
- Pedagogical Knowledge (PK) Integration: Implement active learning strategies through BIM by use project-based learning where students use BIM software to design and analyse building models for a specific project. Encourage collaborative learning by utilizing BIM's shared model features for team projects.
- Content Knowledge (CK) Focus: Ensure a strong foundation in architectural principles, construction methods, and building codes that students will apply within the BIM environment.
- Technological Pedagogical Knowledge (TPK) Emphasis: Dedicate time to exploring how BIM software features can enhance specific teaching methods. Utilize BIM's visualization capabilities to explain complex concepts like building systems or spatial relationships. Leverage BIM's data analysis tools to teach students about energy efficiency or sustainability considerations.
- Technological Content Knowledge (TCK) Understanding: Integrate lessons on how BIM software represents construction elements and building data within the models. Discuss how BIM models can be used for quantity take-offs or clash detection. Explore how BIM data can be used for facility management or lifecycle analysis.
- Pedagogical Content Knowledge (PCK) Application: Designate specific BIM software features or functionalities to address various learning objectives. Introduce basic modelling tools for early understanding of spatial relationships. Introduce advanced features like energy simulations for later design optimization stages.

2.6.1.4 The AiC BIM Body of Knowledge

The Academic Interoperability Coalition (AiC) published a framework in 2015 that explores the Building Information Modelling Body of Knowledge (BIMBOK) (Mayo et al., 2018). This framework offers a structured approach to BIM education by addressing BIM use cases from four key perspectives (Mayo et al., 2018; Wu et al., 2018; Wu et al. 2021):

- Levels of implementation: This perspective focuses on the planning, coordination, management, and execution of BIM within architectural projects. Architectural education should equip students to implement BIM throughout the design and construction process. This includes teaching them BIM-enabled collaboration, information management, and project coordination skills. Courses and workshops can provide hands-on experience with BIM software for tasks like 3D modelling, clash detection, quantity take-offs, and construction scheduling.
- Role of the user: Understanding the different roles involved in BIM projects is crucial for architects to collaborate effectively in multidisciplinary teams. Educational programs should provide students with insights into the roles of designers, contractors, facility managers, and consultants within the BIM workflow. Encouraging interdisciplinary collaboration and practical experience working in simulated project teams allows students to understand the perspectives and requirements of different BIM users.
- Organisational and project considerations: Architectural education should address both the strategic implications of BIM adoption within architectural firms and project-specific needs. Students should learn about the impact of BIM on workflows, staffing requirements, and client expectations. Project-based learning experiences can help students understand the practical challenges and opportunities associated with implementing BIM in architectural projects of varying scales and complexities.
- Levels of performance: Categorizing BIM performance into entry-level, mid-level, and full-performance stages provides a framework for assessing students' proficiency and preparing them for professional practice. Architectural programs should offer opportunities to progress through these levels by gradually increasing the complexity of BIM tasks and projects. Assessments should evaluate students' ability to meet BIM performance criteria and demonstrate proficiency in BIM-related skills and competencies.

In addition, The AiC BIM Body of Knowledge (BOK) can serve as a cornerstone for BIM education by outlining the fundamental Knowledge, Skills, and Abilities (KSAs) necessary for individuals to excel in the field. These core competencies represent the building blocks of BIM proficiency and ensure a well-rounded understanding of the technology and its applications. The following are some areas covered by the BOK:

- BIM Software: Proficiency in using BIM software is essential. The BOK identifies the key functionalities and workflows within these software platforms, encompassing areas like 3D modelling, creating construction documentation, and extracting valuable data from the BIM models.

- Interoperability: Since BIM workflows often involve collaboration between various disciplines using different software, understanding how to achieve interoperability between these platforms is crucial. The BOK equips educators with knowledge of file formats, data exchange protocols, and strategies for ensuring seamless information flow throughout the project lifecycle.
- Collaboration Techniques: BIM is all about fostering collaboration among project stakeholders. The BOK highlights essential collaboration techniques like using common data environments, coordination meetings, and issue-tracking tools to facilitate effective communication and problem-solving within a BIM-enabled project.
- Project management in a BIM context: BIM impacts how projects are managed. The BOK addresses the integration of BIM processes within project schedules, cost estimates, and risk management strategies. This equips students with the ability to leverage BIM to optimize project delivery and achieve desired outcomes.

2.6.1.5 The NBS Periodic Table of BIM

BIM has become an essential tool for architects, transforming design workflows and fostering collaboration. As the AECO sectors embrace BIM, integrating it into educational programs becomes increasingly crucial. The National Building Specification's (NBS, 2016) Periodic Table of BIM, with its 78 elements across 10 technical domains, provides a comprehensive framework for BIM integration based on the practice implementation of BIM (**Annex 6**). This section explores how architectural education can be restructured using the Periodic Table of BIM, aiming to equip students with the necessary BIM proficiency for successful careers.

By strategically aligning curriculum content with the ten technical domains of the Periodic Table of BIM, architectural programs can ensure a holistic understanding of BIM principles and practices. The following is a breakdown of how each element can support BIM education integration:

- Strategy: Courses could focus on defining BIM implementation strategies within architectural firms, aligning BIM with organizational goals, and establishing a roadmap for BIM adoption.
- Foundations: Emphasis should be placed on data integrity, model accuracy, and adherence to project standards. Core courses covering fundamental principles of BIM modelling and information management will lay the groundwork for further exploration.
- Collaboration: Interdisciplinary teamwork skills are fostered through courses that encourage collaboration with other disciplines. These courses can promote a culture of seamless information sharing and collaboration, a key aspect of BIM workflows.

- Process: Systematic approaches to creating, managing, and utilizing information in projects are crucial. Curriculums should integrate standardized workflows and project management methodologies specifically designed for BIM environments.
- People: Developing students' technical skills, knowledge, and collaborative abilities is essential for success in BIM-enabled project teams. Courses that emphasize these aspects will prepare graduates to contribute effectively to project success.
- Technology: Hands-on experience with BIM software applications and technologies is vital. Curriculums should include training on essential tools for BIM modelling, visualization, and analysis, preparing students for the technological landscape they will encounter in practice.
- Standards: Commitment to industry standards and protocols for information exchange ensures consistency and interoperability across projects. Architectural programs can emphasize the importance of these standards by incorporating them into coursework and project requirements.
- Enabling Tools: Specific software applications and technologies that support BIM processes can be integrated into relevant courses. This allows students to explore and utilize tools relevant to their future careers, fostering familiarity and confidence in using them.
- Resources: Architectural programs should address the financial, human, and technological resources required for successful BIM implementation. By discussing resource constraints and optimization strategies, students are better prepared for real-world scenarios.
- Digital Plan of Work (DPoW): Students should be exposed to the concept of a DPoW, which outlines the digital processes and workflows within BIM implementation. By understanding the DPoW framework, students can learn to manage projects from inception to completion using BIM methodologies.

The Periodic Table of BIM as a framework offers a systematic approach to equipping future architects for the digital future. Graduates will possess the skills, knowledge, and competencies needed to thrive in a BIM-enabled architectural practice. Further research and collaboration can optimize BIM education within architectural curriculums and foster innovation in the profession.

2.7 Findings from the Literature Review

A summary of the main findings of the literature review can be highlighted as follows:

- For BIM definition, individual researchers and institutes were interested in BIM definition. BIM definition is not unique, but its functionalities and a vast collection of tools make it exceptional. BIM is primarily defined by its use of information technology for data collecting, its status as a computer-assisted graphical visualisation tool, and its capacity to generate simulation models for analysis and calculation.

- BIM has the ability to retain its efficiency throughout the whole project lifecycle. The use of BIM in architectural practice has been extended from 2D to nD. The capabilities of BIM rely on the incorporation of numerous systems to identify any probable faults before construction and, as a result, to avoid risks, financial losses, and wasteful use of time.
- The awareness and adoption of BIM in professional practices has increased worldwide. Developing countries are gradually recognizing the value of BIM and taking steps towards its adoption, albeit at a slower pace, due to challenges in resources and awareness. Developed countries, on the other hand, have achieved a higher level of awareness, adoption, and integration of BIM. BIM consists of the use of technology and processes in architectural practice. The added value from its adoption is the main reason for its rapid growth among architectural and construction companies. Architectural professionals have used BIM during the design, construction, and operation stages to manage budgets, the time spent on the project, and the quality of materials.
- BIM is an innovative digital technology tool that has attracted much attention from individuals and firms. However, it still needs wide recognition and adoption in professional practice and the educational curriculum. This is the primary reason for the gap formation when transitioning from college to the working world.
- The main barriers to BIM implementation are the lack of a workforce possessing BIM skills has been acknowledged as a significant challenge, alongside with absence of a standardised approach, the high cost of the application, and legal issues. These challenges have negatively impacted the implementation of BIM in architectural practice. It is thus of considerable importance that architectural programmes focus on training future architects in the capabilities and skills of BIM.
- BIM integration into the architectural curricula has witnessed four phases of development: (1) the transition phase from AutoCAD to BIM; (2) the integration phase of BIM being established as a standalone course; (3) the integration into the cross-disciplinary core curriculum; and (4) BIM enabled architectural education.
- Architectural schools have embedded BIM education in various forms, including (1) standalone BIM courses, (2) integration with existing courses, and (3) the integration of BIM into the design studio. Each course has presented BIM from a different aspect, depending on whether it is taught as a technology or process.
- The appraisal of BIM deployment in architectural programme reveals a preference for standalone courses over an integrated curriculum. BIM deployment methods are recommended to include both approaches in the architectural curriculum, particularly within the predominance of design studio courses.
- BIM has been taught at different academic levels in undergraduate and postgraduate. Teaching BIM at academic levels should balance traditional knowledge and the BIM learning curve. Universities are encouraged to select the suitable undergraduate level to integrate BIM based on learner needs and proficiency, pedagogical considerations, and practical university facilitation and capacity issues.

- BIM learning outcomes in undergraduate architectural education can be categorised into knowledge and understanding, and practical and transferable skills.
- Students must obtain a decent degree of architectural knowledge. This helps students better comprehend BIM and be inspired to put forth their own efforts to develop new abilities. Educators also believe that the BIM prerequisite within the programme supports its integration by all universities in their efforts to improve their learning quality and remain competitive.
- Policies on the use of emerging technologies can be successful only if formulated based on the perspective of the young adults who will implement them. Teaching experience and qualification of intended users must be considered when making policies on the adoption of emerging technologies like BIM.

There remains an urgent need to overcome the various challenges limiting the full implementation of BIM into architectural programmes. These challenges can be grouped into staff and students, education process, and education product. Challenges identified from previous studies can be summarised on the following three areas, including

- Staff and students: a lack of staff qualified to teach BIM, a lack of academic and professional collaborations, and a lack of students interested in learning BIM.
- Education Process: a lack of suitable education infrastructure, facilities, resources, software and hardware, and a lack of research and evaluation.
- Education Product: a lack of clear university vision and plan related to BIM, lack of teaching strategies, and obsolete curriculum.

2.8 Identification of Research Gaps

According to the extensive literature review described above, it has been noticed that the integration of BIM into undergraduate architectural education presents a critical gap in current research and practice. Despite numerous efforts to incorporate BIM into architectural education, there remains a significant absence of a comprehensive and formal approach for its adoption in undergraduate architectural programmes. This gap is exacerbated by the rapid digital transformation within the AECO sectors, which increasingly demand proficiency in BIM from graduates (Liu, 2012; Abbas et al., 2016; Shelbourn et al., 2017) , and it is urgent for research into architectural education to find a technical solution that can tackle the challenge and fill the knowledge gap.

BIM integration in architectural education is often inconsistent, with varying degrees of implementation across different institutions. Some schools have adopted standalone BIM courses, while others attempt to embed BIM into existing design studios and technical courses (Ahn and Kim, 2016; Lopez-Zaldivar et al., 2017; Eastman, 2018). These approaches often result in students receiving an uneven education in BIM, with a lack of depth and continuity in learning (Clevenger et al., 2010; Solnosky and Parfitt, 2015; Abdirad and Dossick, 2016; Coates et al., 2018), and such a situation can eventually decrease the professional competence of students in architectural education towards their career development.

The literature primarily focuses on specific aspects such as teaching strategies, methods, materials, curriculum design, and student perceptions (Clevenger et al., 2010; Solnosky and Parfitt, 2015; Abdirad and Dossick, 2016; Coates et al., 2018). However, there is a notable gap in research that addresses a strategic plan for the progressive integration of BIM throughout the entirety of an undergraduate architectural education programme (Maharika et al., 2020; Böes et al., 2021), and this knowledge gap together with other identified tactic issues in relation to the integration of BIM in architectural education indicate the need for research into a strategic approach to integrating BIM into architectural engineering curriculum.

As the AECO sectors continue to evolve digitally, graduates equipped with BIM knowledge and skills are essential for industry competitiveness and innovation (Solnosky and Parfitt, 2015; Olugboyega and Windapo, 2019). Effective BIM integration in architectural education not only prepares students for professional practice but also ensures they contribute significantly to sustainable building practices and digital workflows (Mahran et al., 2022; Liu et al., 2021).

Therefore, it is a research task for the strategic approach to BIM integrated architectural education to support the development of BIM knowledge and skills among students at different levels. In order to fill the knowledge gap identified through literature review, the research described in this thesis aims to develop an educational framework that outlines the progressive integration of BIM knowledge and skills in undergraduate architectural education. This framework need to tackle the following 6 key issues identified as essentials through literature review, and these include (1) Developing a clear strategy for BIM education that aligns with the overall vision and operational goals of architectural programmes. (2) Creating a curriculum that integrates BIM progressively, ensuring students develop comprehensive skills throughout their education. (3) Ensuring that both educators and students continuously develop their BIM skills in line with industry advancements. (4) Fostering collaborations between academia and industry to keep the curriculum relevant and beneficial for students' future careers. (5) Providing the necessary technological infrastructure and resources to support effective BIM education. (6) Continuously evaluating and improving the educational processes to ensure the effective integration of BIM. By covering this area this framework can provide a structured and systematic approach to embedding BIM into undergraduate architectural education, thereby filling a critical gap in the existing literature and practice.

2.9 Summary

This chapter provides an up-to-date overview of BIM with a particular focus on BIM education regarding its status and integration in AECO sectors and architectural education. BIM is a technology that uses data collection, computer-aided visualization, and simulation for architectural design. It improves efficiency throughout a project's lifecycle and reduces errors. BIM use is growing in the AECO sectors worldwide. However, there is a need to bridge the gap between BIM skills taught in architectural schools and those required in the workplace.

The chapter also discusses challenges to implement BIM education, including a lack of qualified instructors, suitable resources, and clear curriculum plans. It emphasizes the need for universities to adapt their programmes to meet the AECO sectors' growing demand for BIM expertise. To achieve this transformation, the chapter explores various academic initiatives and frameworks that can guide the development of BIM education programmes. These frameworks include the CDIO Approach, ESD Framework, TPACK Framework, the NBS Periodic Table of BIM, and the AiC BIM Body of Knowledge. By implementing these frameworks and addressing the identified challenges, architectural education can create a new generation of BIM-ready graduates equipped with the skills and knowledge to thrive in the ever-expanding BIM market.

Chapter 3: Research Background in Libya

The study of a country's historical, social, and economic status is essential for understanding the architectural education and practice in that country. The challenges facing undergraduate architectural education in developing countries, such as Libya among Arab countries, may differ from developed countries due to national history and culture. This chapter aims to provide background information on Libya's geography, population, culture, and economy and outline the development and challenges of the AECO sectors and education in general and architectural education in specific. This chapter also addresses BIM implementation challenges in the AECO sectors and architectural education and their importance for architectural education. Understanding these institutional factors is crucial for identifying potential influences of teaching BIM technology on undergraduate architectural education practices at Libyan universities.

3.1 Country Background

The nation of Libya is situated in a strategically significant geopolitical location that connects diverse cultural spheres, including those of the Arab, African, Islamic, and European regions. The identity of Libya has been shaped by its association with various factors. This section provides an overview of Libya's geographical location and its significance in location, population distribution, and economy.

3.1.1 Geographical Characteristics

The geographical location of Libya plays a significant role in shaping its climate, economy, and demographics. The nation is situated in the northern region of Africa, with a distinct adjacency to the Mediterranean Sea in the north. This nearness to the sea influences the climate of coastal regions, characterizing it with a Mediterranean climate. In contrast, the remaining parts of the nation, which are far from the sea, experience a dry desert climate due to their proximity to the Sahara Desert. The borders of Libya stretch across its neighbouring countries of Tunisia and Algeria in the west, Egypt and Sudan in the east and southeast, and Chad and Niger to the south. This strategic location of Libya makes it an essential hub for regional and international trade, providing a gateway to and from the African continent (Cordell et al., 2023).

The country boasts a massive land area of roughly 1,759,540 square kilometres, making it the fourth-largest country in Africa and the 17th-largest globally. Libya's extensive coastline, spanning over 1,770 kilometres, provides ample strategic support to its sea trade and naval activities (CIA, 2021). The majority of Libya's population resides in the coastal regions due to the area's more favourable climate. They derive the perks of proximity to the ocean, which enhances trade, tourism, and fishing activities. Libya's two primary urban centres, Tripoli and Benghazi, are the most populated cities and serve as vital trade hubs. However, the central and southern regions are less populated, experiencing harsher climatic conditions and lower economic activities. These areas are mainly used for livestock rearing and low-scale agricultural activities.

3.1.2 Population and Cultural Aspects.

The population of Libya has undergone significant changes and trends over the years. According to data from Macro Trends (2023), Libya's population is estimated to be around 6.7 million in 2023, a relatively minor population count compared to other countries in North Africa.

Historical records show Libya has experienced substantial population growth since 1954 (See **Table 3.1**). The population increased from 1,088,873 million in 1954 to over three million by 1981, indicating a rapid growth rate during this period, peaking at 5%. However, the population growth rate declined in the 1990s, dropping to 2% due to the cessation of development initiatives and global sanctions imposed on Libya. The country experienced a rebound in population growth in the early 2000s, reaching 2.5% following the lifting of sanctions and increased international engagement. However, political instability in Libya had a notable impact on population growth in the subsequent years, with a decrease of -5% in 2011 and 2012, coinciding with political unrest and revolution.

Since 2013, the population growth rate has steadily increased, reaching 1.3% by 2023. This gradual upward trend may indicate a stabilization of the population growth rate following the period of political instability. As Libya continues to rebuild its infrastructure and stabilize its political situation, monitoring its population growth rate and identifying the factors driving its sustainability is essential.

Table 3.1: Libyan population history

Year Range	Average Population	Average Growth Rate
2023-2019	6,677,567	1.27%
2018-2014	6,127,992	1.66%
2011-2012	5,869,870	-5.14%
2010-2009	6,135,316	2.20%
2008-2004	5,813,007	2.58%
2003-1999	5,450,858	2.44%
1998-1994	4,900,135	2.05%
1993-1989	4,361,601	2.64%
1988-1984	3,760,717	3.76%
1983-1979	2,956,547	5.04%
1978-1974	2,453,389	5.28%
1973-1969	1,988,513	2.48%

Year Range	Average Population	Average Growth Rate
1968-1964	1,739,030	2.88%
1963-1959	1,553,603	3.49%
1958-1954	1,252,007	2.75%

The Libyan populace comprises diverse ethnic groups, predominantly constituted by individuals of Arab or Arab-Berber descent. The official language in Libya is Arabic, and English is commonly utilized in commercial transactions within metropolitan regions, while Italian and French are also used to a comparatively lower degree. Certain minority groups utilize Berber dialects, specifically Tamazight (the language of the Amazigh tribe) and Tamahaq (the language of the Tuareg tribe).

The dominant cultural influences in Libyan society are derived from Arab and Islamic traditions. The linguistic, religious, and cultural dimensions of the Arabic language, Islam as the state religion, and the societal values of extended family, tribe, and clan substantially influence the Libyan populace's lifestyle and worldview. The majority of the Libyan population follows the Sunni branch of Islam.

3.1.3 Economy of Libya

The economy of Libya has undergone significant challenges in recent years, primarily due to political instability and armed conflict (Khan and Mezran, 2013; Swessi, 2022). Despite being blessed with abundant natural resources, particularly oil, and gas, these issues have severely impacted the country's economic stability and development. Libya possesses the largest proven oil reserves in Africa, making the oil and gas sector the core of its economy. Oil production and exports served as the country's primary revenue source for many years. However, the revolution in 2011 and subsequent political turmoil disrupted the oil industry's operations, leading to a substantial decline in production. According to the International Monetary Fund (IMF, 2019), Libya's oil production plummeted from 1.2 million barrels per day before the civil war to less than 200,000 barrels per day in 2019. Consequently, the government faced a severe shortage of funds as it heavily relied on oil revenues to finance its budget and public services.

The ongoing political instability has also hindered the diversification and development of other industries, such as the AEC sector. Despite its immense potential, the AECO industry has struggled to grow due to a lack of investment, a shortage of skilled workforce, and an unstable regulatory environment (Osman, 2019). These challenges have impeded the country's economic growth and hindered the realization of substantial revenues from sectors beyond oil and gas. Moreover, the absence of political stability has made it difficult to attract foreign direct investment, which is vital for the growth and development of the AECO sectors (Bourhrous, 2021). Until these challenges are effectively addressed, Libya will continue to rely heavily on oil and petroleum products as its primary source of income.

In addition to impacting industries, the political instability has had detrimental effects on Libya's higher education sector (Zaed and Chen, 2021). Before the revolution, the government had significantly emphasized improving higher education by allocating substantial funding to universities and colleges (Tamtam, Gallagher, and Naher, 2011). The goal was to develop a skilled workforce capable of contributing to the country's economic growth. However, the continued conflict and instability have disrupted the educational environment, resulting in challenges for higher education institutions. The ongoing conflict has impeded the expansion and progress of the sector, hindering the development of a skilled workforce.

It is crucial for Libya to prioritize achieving political stability and security to create a favourable environment for economic growth. This includes establishing solid institutions, ensuring the rule of law, and fostering a business-friendly regulatory framework. By diversifying its economy and reducing its dependency on oil, Libya can promote the growth of sectors like tourism, agriculture, manufacturing, and renewable energy.

3.2 AECO Sectors in Libya

The AECO sector in Libya is a vital sector that contributes significantly to the country's economy. The AECO sectors include a range of professional services, such as architecture, urban planning, construction management, and infrastructure development, all aimed at improving Libya's built environment. Despite the recent political and economic challenges, the AECO sectors remain resilient and attract investments and partnerships from global players. This section aims to provide a holistic background of the AECO sectors in Libya, the use of digital technologies in the AECO sectors and its challenges, and the role that the AECO sectors can play in the post-conflict reconstruction of the country.

3.2.1 The Holistic Background of the AECO Sectors in Libya

The AECO sector in Libya has been an essential contributor to the country's economy. It is one of the industries that creates employment opportunities and contributes to the growth of the nation (Elsonoki and Yunus, 2020). The Libyan government, for a long time, has prioritized and invested in the AECO sectors to build and grow the country's infrastructure. However, the industry has faced several challenges in recent years. These challenges include:

- Political instability: Ongoing political disorder and conflicts in Libya have led to a lack of stability in the governance system (Goenaga, 2017). This instability has resulted in a stop in construction projects, delays in approvals, and a decline in foreign investment.
- Lack of skilled workers: Despite a high unemployment rate, the AECO sector has a shortage of trained and experienced workers (Osman and Baldry, 2017). This shortage can be attributed to inadequate training facilities, low wages, and a lack of interest in the field. It has led to decreased productivity, quality, and safety concerns.

- Reliance on foreign companies and workers: The AECO sectors in Libya heavily rely on foreign companies and workers to execute construction projects. This reliance limits the transfer of technology, know-how, and expertise to Libyan workers, hindering the sector's progress and long-term sustainability.
- The economic impact of COVID-19: The outbreak of COVID-19 has further exacerbated the challenges faced by the AECO sectors in Libya. It has caused disruptions, delays, and financial difficulties, impacting the progress and viability of construction projects.

On a positive note, the AECO sectors in Libya have great growth potential. The Libyan government has acknowledged this potential and has introduced measures to attract foreign investment and partnerships. Additionally, the government has invested in several AECO training programmes to develop and train the workforce. Moreover, the sector's adoption of innovative technology has helped improve efficiency and quality (Elghdban et al., 2023). With the recent advancements in digital technologies, the sector can create building models, increasing accuracy and collaboration and reducing the likelihood of errors and rework. The use of digital technology also improves sustainability by reducing waste and minimizing the carbon footprint of construction projects.

3.2.2 The Use of Digital Technologies in the Libyan AECO Sectors

The integration of digital technologies in the Libyan AECO sectors is a transformative shift that is poised to revolutionize the way the industry operates, although the AECO sectors in Libya are lagging in digital technology adoption, which has adversely affected its competitiveness (Elsonoki and Yunus, 2020; Elghdban et al., 2023). Nonetheless, Libyan professionals have recognised the potential benefits of digitalisation, which encompasses a variety of activities from designing and constructing infrastructure to managing and maintaining built assets. A primary catalyst for this digital transformation is the need to enhance productivity and project outcomes (Zaed and Chen, 2021). This integration is driven by different factors, including technological advancements, increased demand for infrastructure development, and a desire to enhance efficiency, sustainability, and competitiveness.

One of the most fundamental digital tools used in the Libyan AECO sectors is Autodesk AutoCAD, which allows for the creation of accurate 2D digital drawings (Zaed and Chen, 2021). These drawings serve as the foundation for construction plans and technical documentation. While 2D drawings remain an essential part of project documentation, they are now complemented by more advanced technologies to improve the overall efficiency of projects.

The introduction of Autodesk Revit, Graphisoft and ArchiCAD applications has been crucial to improving professionals’ skills related to BIM. These applications allow for the creation of structured information linked to 3D digital models, providing a comprehensive and interconnected view of the project (Aljad, 2023). This 3D representation enhances the comprehensibility of the project for architects, engineers, and other stakeholders. In addition, digital technology, such as BIM, can potentially address some of the long-standing challenges in Libya's AECO sectors (Aljad, 2023; Elghdban et al., 2023). BIM can improve collaboration between project stakeholders, data accuracy, and streamlined processes. With all project information integrated into one platform, BIM promotes better coordination, efficient problem-solving, and improved decision-making throughout the project lifecycle.

Despite the potential benefits, the introduction of digital technologies in Libya's AECO sectors faces several challenges (Solla et al., 2023). Cost remains a significant concern, as implementing technology can be expensive. The government and private sector must weigh the long-term benefits of increased efficiency and reduced costs against the initial investment in technology and training.

Resistance to change is another hurdle that needs to be addressed. Individuals and organizations within the sector may hesitate to adapt to new digital tools and processes. Education and training initiatives can play a critical role in easing this transition and ensuring that industry professionals are well-prepared to use advanced technology such as BIM effectively (Solla et al., 2023).

Inadequate planning and a lack of awareness about the benefits of digital technology adoption are also challenges that need to be overcome (Saleh, 2015). Government initiatives to promote BIM and targeted awareness campaigns can help address these issues by showcasing the advantages of digital technology in the AECO sectors.

BIM technology used to create and manage 3D models of buildings and infrastructure projects is vital for Libya's AECO sectors. It represents an opportunity to address longstanding challenges, improve collaboration, and enhance project efficiency. Digital technology is no longer just an option but necessary for the industry's future growth and success.

3.2.3 The Significance of the AECO Sectors in Post-Conflict Stage

The AECO sector plays a crucial role in the post-conflict stage in Libya. After years of conflict, much of the country's infrastructure has been damaged or destroyed, ranging from roads, airports, and other transportation infrastructure to schools, hospitals, and public buildings (Goenaga, 2017). The AECO sector is responsible for designing, engineering, and constructing new infrastructure and repairing and rehabilitating damaged or destroyed infrastructure. As such, it is essential in the rebuilding process and the revival of the local economy. In addition to infrastructure projects, the AECO sectors can also play a vital role in housing for those displaced by the conflict (Elsonoki and Yunus, 2020). This includes the provision of social housing for low-income families and the reconstruction of damaged homes and buildings. The construction and repair of accommodation can provide stable employment opportunities for locals and can contribute to jump-starting the economy by injecting money into the local market.

In addition to these specific contributions, the AECO sectors can play a more general role in the post-conflict period by providing jobs, training, and skills development (Saeed et al., 2014). This can help to create a more skilled workforce, which will be essential for economic recovery.

The AECO sectors can potentially play a significant role in the post-conflict stage in Libya. By working with other stakeholders, the sector can help rebuild the country and create a better future for its people. However, the sector has faced several challenges to growth during the post-conflict period. These challenges include:

- Security: The security situation in Libya remains volatile, which poses a challenge for the AECO sectors. Contractors need to be able to operate in a safe and secure environment, and they need to be able to protect their workers and equipment from harm.
- Lack of skilled workers: There is a shortage of workforce in Libya, which can make it difficult for the AECO sectors to find the workers it need (Osman, 2019). Contractors may need to import skilled labour from other countries, which can be expensive and time-consuming.
- Lack of funding: The Libyan government is facing a financial crisis, which has made it difficult to fund infrastructure projects (World Bank, 2021). This has led to delays in some projects and made it more difficult for contractors to get paid.

Despite these challenges, the AECO sector has the potential to make a significant contribution to the post-conflict stage in Libya. By working with other stakeholders, the sector can help rebuild the country and create a better future for its people.

3.3 Architectural Education in Libya

The primary goal of architectural education is to equip students with the necessary skills, knowledge, and expertise to design functional, sustainable, and aesthetically pleasing buildings and public spaces that meet the needs of a specific society. This section aims to provide a comprehensive overview of architectural education in Libya, covering aspects such as digital technologies, the educational system, challenges faced, and the essential role of architectural education in post-conflict stage efforts.

3.3.1 The Holistic Background in Architectural Education in Libya

Architectural education in Libya has a holistic background that reflects the country's commitment to aligning higher education with sustainable development goals. The introduction of architectural education in Libyan universities during the late 1960s was an extension of engineering programmes (Mezughi, 2015; Zaed and Chen, 2021). Although it was a significant step towards developing the architectural education, the curriculum faced numerous challenges. For nearly two decades, the curriculum remained stagnant, and there were limited opportunities for architecture students to explore and enhance their skills. This situation hindered the growth of the architectural practice and created a gap in the architectural education system in Libya.

However, the introduction of the semester system in the early 1980s brought a new wave of change to the architectural curriculum. This new structure brought about a more organized and structured approach to teaching and learning. Under this system, the curriculum was divided into semesters, and students could take custom-made core and elective courses to provide a comprehensive approach to architectural education (Mezughi, 2015). Despite these changes, the architectural curriculum in Libya continues to face challenges. The most significant hindrance is the lack of resources and materials to support teaching and learning and practical applications of concepts. As a result, most students have to rely on theoretical knowledge as the practical aspect of the field is often ignored.

As a result, the Libyan government is committed to enhancing higher education, including architectural education, and aligning it with the 2030 sustainable development goals. The government acknowledges that a thriving AECO sector is essential to the country's economic development and has prioritized the sector's growth. Additionally, the government is working towards creating an environment that fosters research and innovation in the field (Ministry of Education, 2019). This plan can create more opportunities for students to explore and enhance their skills and ensure that the curriculum remains relevant and up to date with the latest trends and industry practices. It is expected that with the continued efforts to improve the architectural curriculum and create an enabling environment, Libya's architecture industry can be increased, creating jobs, and boosting the country's economic growth.

3.3.2 Architectural Education System at Libyan Universities

The architectural education programme of Libyan universities plays a crucial role in shaping the country's environment and producing new generations of skilled architects. The architectural programme takes a structured approach to provide students with theoretical knowledge, practical skills, and creative thinking necessary for the field of architecture. Libyan universities offer two types of undergraduate programmes in architectural, namely architectural and urban design and planning. However, there are variations in course outlines and facilities across different universities, such as the University of Tripoli, the University of Zawia, and Omar Al-Mukhtar University. Each institution offers these programs with various course outlines and facilities (University of Tripoli, n.d.; Omar Al-Mukhtar University, n.d.; University of Zawia, n.d.). As a result, two separate undergraduate programmes have emerged, leading to graduates with similar architectural and urbanism skills and responsibilities (See **Figure 3.1)**

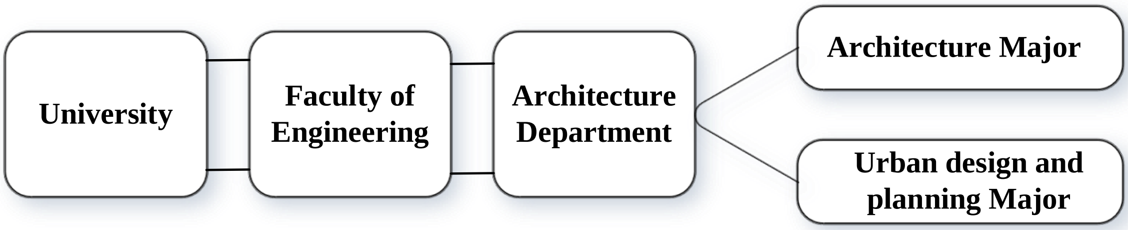

Figure 3.1: The undergraduate architectural education system at Libyan universities

Initially, as shows in **Figure 3.1** students join the faculty of engineering at the university for one year to learn general subjects that provide basic knowledge before specializing in their major. Although this initial period is beneficial for guiding students in selecting a major, it fails to educate them about other disciplines. For instance, the University of Tripoli's Department of Architectural follows a programme where new students enrol in the engineering faculty for the foundation year, which includes teaching basic science subjects. Subsequently, students join the Department of Architectural for four years (eight semesters) and are awarded a bachelor's degree in architectural engineering with no majors specified (University of Tripoli, n.d.). The Libyan authorities express limited confidence in graduates who don't meet the required standards, including sufficient training in national building codes, quality assurance, and control (Mezughi, 2015). Consequently, architectural education graduates lack a clear professional identity representing their duties and skills to the industry, hindering their ability to meet market demands.

To address this issue, the political reforms of 2011 led architects to demand the establishment of the Libyan Architectural Association, which later became the Libyan Board of Architecture (LBA) and the Libyan Institute of Architects (LIA). These associations now play a mutual role in coordinating the restructuring process between the requirements of architectural education, professional practice, and market needs. The coordination aims to bridge the gap between university outcomes and labor market demands.

3.3.3 The Use of Digital Technologies in Libyan Architectural Education

The integration of digital technologies in architectural education in Libya has become critical for improving the quality of teaching and preparing students for the evolving demands of the digital AECO sectors. As a result of digital technology globalisation, the intellectual discussion has increased on what constitutes the whole body of architectural knowledge to be imparted to future professionals (Uwakonye et al., 2015). The digital revolution emphasised a need to review the current architectural curriculum in Libyan architectural schools with consideration of increased usage of computer content. The integration of digital technology can achieve numerous educational goals with great efficiency, driving qualitative changes in teaching and learning. Integrating technology is more than just teaching basic programming skills and implementing in-class software programmes without requiring a separate computer class (Kenan et al., 2015). Technology integration must occur in the educational system to facilitate in-depth learning. There are four main learning elements that must be encouraged: (1) participation in groups, (2) active communication, (3) connection to real-world experts, and (4) regular interaction and feedback (Elshaikhi, 2015). Efficient technology incorporation is accomplished when standard and transparent technology promotes curricular objectives.

Libyan architectural schools have started to train students in using the most widely used and beneficial programmes, using professional practices such as computer-aided design (CAD). The incorporation of CAD increases the number of ideas and simulations encountered by students during simulation operations in synthesis activities (Zaed and Chen, 2021; Aljad, 2023). The ability of students to gain expertise and design ideas for innovative architectural products was further strengthened by incorporating CAD into the design practices. This software is the foundation of many architectural programmes, as it allows students to create precise 2D digital drawings, which are essential for architectural design and technical documentation. While 2D CAD continues to be the mainstay of architectural education, there is a growing awareness of the potential benefits of tools and applications, particularly in fostering a deeper understanding of architectural design and construction processes (Zaed and Chen, 2021). Software such as Autodesk Revit and Graphisoft ArchiCAD offers a multidimensional approach, enabling students to create 3D models and integrate structured information in the same models.

Integrating digital technologies, including BIM, into architectural education in Libya is an important step to address the need to equip students with digital skills that better prepare them for the evolving AECO sectors (Aljad, 2023). As the architectural field shifts towards more collaborative and information-driven practices, it is imperative that students have exposure to advanced technologies such as BIM that improve the design process, data accuracy and integrated project management. However, the adoption of BIM in architectural education is still in its nascent stages and faces some challenges (Zaed and Chen, 2021; Aljad, 2023). These challenges include limited software and hardware access, faculty development to effectively teach BIM, and the predominance of 2D CAD in the curriculum (Zaed et al., 2021). Overcoming these barriers is essential to ensuring that architectural students in Libya can leverage the full potential of digital technology in their education.

Libyan academic institutions need to put more effort into incorporating BIM and related digital tools into their architectural programme to drive innovation and enhance the quality of architectural education. With its structured information and 3D modelling capabilities, BIM technology offers a valuable resource for students to explore architectural design and construction concepts more comprehensively.

3.3.4 Challenges of Architectural Education Development in Libya

Architectural education in Libya faces significant difficulties due to inherent problems common to developing countries and specific socio-economic circumstances. The country's higher education system, including architectural education, struggles to improve educational facilities' quality, increase educational spending productivity, and adopt modern learning and teaching approaches (Triki, 2016). A study identifying higher education difficulties in Libya revealed that the lack of appropriate planning, outdated curricula and shortage of trained teachers are the main obstacles to education quality (Khalil and Halis, 2017). Other significant factors contributing to the challenges include limited use of technology in learning and teaching and inadequately equipped laboratories. In addition, Libya's ongoing political instability exacerbates these fundamental hindrances to educational development (Rhema and Miliszewska, 2010; Alzain, Clark and Ireson, 2014; Khalil and Halis, 2017).

The following are the main challenges that need to be addressed to improve architectural education in Libya:

- Obsolete curriculum: Many architectural education programs in Libya use outdated curricula that fail to reflect the latest trends and developments in the field, especially the integration of digital technology (Zaed and Chen, 2021). The lack of timely updates can create a gap between students' knowledge and skills and the evolving needs of the profession.
- Limited use of digital technology: The integration of digital technology in teaching and learning processes is crucial for the advancement of architectural education. However, in Libya, digital tools and technologies are limited, hindering students' exposure to modern tools and their ability to adapt to technological advancements in the field (Aljad, 2023).
- Limited resources: The educational system in Libya, including architectural education, suffers from limited resources (Aljad, 2023). Insufficient funding for infrastructure, equipment, and materials hinders the ability to provide a conducive learning environment and practical hands-on experiences for students.
- Outdated infrastructure: Many educational institutions in Libya struggle with outdated infrastructure, including classrooms, laboratories, and design studios (Zaed, et al., 2021). The lack of modern facilities and technology impedes the delivery of contemporary and innovative architectural education.
- Faculty qualifications and professional development: Highly qualified and experienced faculty members play a crucial role in shaping the quality of architectural education (Zaed et al., 2021). However, attracting and retaining such faculty members can be challenging. Limited opportunities for professional development and low salaries impact the quality and expertise of the teaching staff.
- Limited industry collaboration: Close collaboration between educational institutions and the industry is vital for providing students with practical exposure, internships, and professional development opportunities. However, there may be limited collaboration between architectural schools and the construction industry in Libya, hindering the integration of real-world experiences and alignment of education with industry needs.
- Limited research and innovation: Research and innovation are essential for architectural education. However, limited research opportunities, funding, and a lack of research-oriented culture hinder the development of research initiatives within architectural education in Libya. Insufficient emphasis on research limits the generation of new knowledge, the development of innovative design solutions, and the integration of research findings into the curriculum.

- Lack of professional accreditation: Obtaining professional accreditation is vital for architectural graduates to be recognized internationally and meet the standards of architectural practice (Elghdban et al., 2023). Libyan universities should strive to align their architectural programs with international accreditation bodies, such as the Royal Institute of British Architects (RIBA) or the National Council of Architectural Registration Boards (NCARB). This alignment can enhance graduates' employability and facilitate their professional mobility.

Overcoming these obstacles requires comprehensive education programs encompassing universities, labour market requirements, and students' ambitions. Addressing these challenges necessitates joint efforts from the government, educational institutions, professional organizations, and the industry. Investments in infrastructure, faculty development, research development, and strengthening industry-academia collaboration can contribute to overcoming these challenges and improving the quality of architectural education in Libya.

3.3.5 The Significance of Architectural Education in the Post-Conflict Stage

Architectural education plays a crucial role in post-conflict stage efforts in Libya. After a period of conflict, there is often a need to rebuild and revitalize infrastructure, cities, and communities. Architectural education can help by equipping students with the skills, knowledge, and mindset necessary to contribute meaningfully to this process (Triki, 2016; Zaed and Chen, 2021). One of its key roles is training architecture students to be aware of the specific needs of the local community. In a post-conflict environment, it is vital to rebuild in a manner that addresses the requirements of the people who will utilise the buildings. This entails understanding the community's cultural, social, economic, and environmental contexts. Architectural education can effectively train current and future architects to consider these factors and design buildings that meet the community's needs.

Sustainability is crucial in post-conflict reconstruction, and architectural education is significant in promoting sustainable construction. By educating and training architecture students on the use of sustainable materials and construction techniques and designing adaptable buildings, architectural education contributes to sustainable reconstruction (Lepere, 2020). Furthermore, it raises awareness among students and the public about the importance of post-conflict reconstruction, garnering support for reconstruction efforts and emphasizing the significance of sustainability and resilience. Furthermore, architectural education can contribute to the post-conflict stage by:

- Promoting peace and reconciliation: Through the integration of students from diverse backgrounds and cultures, architectural education can foster peace and reconciliation (Yu and Wyness, 2023). This becomes particularly crucial in post-conflict environments where trust and divisions are often prevalent.

- Encouraging innovation: Architectural education nurtures a culture of innovation in designing buildings and infrastructure. This is vital in post-conflict settings where innovative solutions are often required to address complex challenges.
- Creating employment opportunities: Architectural education can generate job opportunities in the construction industry (Lepere, 2020). This is especially significant in post-conflict environments where high unemployment rates are expected.

In the case of Libya, architectural education can play a substantial role in the post-conflict stage. By considering the needs of the local community, promoting peace and reconciliation, encouraging innovation, and creating job opportunities, architectural education can contribute to the development of a more sustainable and resilient future for the country.

3.4 Key Findings of the Chapter

- Country background: Libya is a North African country. Libya has a population of approximately 7 million people. The country has experienced political instability and conflict in recent years, leading to challenges in various sectors, including the construction industry.
- The AECO sectors in Libya play a vital role in the country's economic development. The political unrest has significantly impacted it, resulting in a decline in infrastructure projects and construction activities. The AECO sector needs modernization and technological advancements to enhance efficiency and productivity.
- Digital transformation in AECO: The integration of digital technologies in the Libyan AECO sectors is poised to bring about a transformative shift, offering the potential to revolutionize the industry's operations. Despite the initial lag in digital technology adoption, this shift is driven by the need to enhance productivity and project outcomes.
- Autodesk AutoCAD is a main application used in the Libyan AECO sectors, enabling the creation of precise 2D digital drawings. These drawings serve as the foundation for construction plans and technical documentation, although more advanced technologies are being integrated to enhance overall project efficiency, including Autodesk Revit, Graphisoft and ArchiCAD.
- Challenges to digital technology adoption: The adoption of digital technologies in Libya's AECO sectors faces significant challenges. These include concerns about the cost of implementation, resistance to change within the industry, and a lack of awareness about the benefits of digital technology adoption. Overcoming these challenges requires government initiatives, training programs, and awareness campaigns to promote the advantages of digital technology, including BIM, in the sector.
- Architectural education in Libya is offered through universities and higher education institutions. The curriculum focuses on theoretical knowledge, design principles, and practical skills necessary for architectural practice. However, there is a need for curriculum enhancement to incorporate emerging technologies and sector practices.

- Importance of digital technology integration: The integration of digital technologies in architectural education in Libya is crucial for improving the quality of education and preparing students for the demands of the digital AECO sectors.
- CAD Usage: Libyan architectural schools have begun training students in widely used software programs, particularly computer-aided design (CAD). CAD enhances students' ability to generate innovative architectural ideas and products, as it enables precise 2D digital drawings that are fundamental for architectural design and technical documentation.
- Importance of BIM: The integration of digital technologies, including BIM, is seen as a critical step in preparing students for the evolving AECO sectors. BIM improves the design process, data accuracy, and integrated project management, aligning with the industry's shift toward collaborative and information-driven practices.
- The integration of BIM into architectural education can enhance the competitiveness of Libyan architects in the global market. It equips students with modern design and construction methodologies, improving their employability prospects. BIM can contribute to the overall development and advancement of the AECO sectors in Libya, leading to sustainable growth and improved project outcomes.

3.5 Summary

This chapter provides a comprehensive overview of the historical, social, and economic factors that shape architectural education in Libya. It highlights the challenges encountered in undergraduate architectural education within developing countries like Libya, which are distinct due to the nation's historical and cultural context. Furthermore, the chapter emphasizes the significance of addressing the key challenges of integrating BIM technology into architectural education and practice. These challenges include limited resources and infrastructure, the need for faculty training and development, curriculum development, and academic-industry collaboration. Overcoming these obstacles is essential to adequately prepare students to meet the evolving demands of the architectural industry and ensure their proficiency in utilizing BIM tools and methodologies.

Chapter 4: Research Methodology

This chapter presents an exploration of the research methodologies applied in the context of this PhD study. It includes an overview of various research methods, outlines the strategies employed for the acquisition of primary data essential for subsequent analysis, and underscores the alignment of these research techniques with the specific objectives of the study.

The methodological approach employed within this study has been designed to fulfil the main research aim and objectives. Key areas addressed in this chapter encompass: (1) philosophical underpinnings of the research, (2) research approaches, (3) research techniques, (4) research design, (5) research phases, and (6) ethical considerations.

4.1 Philosophical Foundations

Research philosophy constitutes the fundamental set of assumptions, beliefs, and principles that direct the researcher's worldview and influence their choices throughout the research journey (Saunders et al., 2015). Research philosophy serves as a lens through which the researcher perceives reality, knowledge, and the nature of the research process itself. Therefore, considerate research philosophy is essential for a number of reasons, including that it facilitates the clarification of the research design, the determination of appropriate research methodologies, and the promotion of innovative approaches (Easterby-Smith et al., 2012). This study adopts a specific research philosophy, acting as a guiding that shapes the methodology and approaches employed.

This study adopts a dual research philosophy, combining interpretivism and positivism, each providing unique perspectives to enrich the exploration of BIM integration within architectural education. The research investigates two perspectives: ontological and epistemological, drawing inspiration from Akkerman et al. (2021) work emphasising the significance of ontology in educational studies.

In adopting an interpretivism ontological stance, this study acknowledges that reality is socially constructed and that individuals assign meanings to their experiences (Wahyuni, 2012; Creswell and Poth, 2016). It recognizes the subjective nature of reality, particularly in the scope of BIM integration in architectural education in Libya. The focus is on exploring the diverse perspectives, beliefs, and interpretations of stakeholders involved in BIM adoption, highlighting the contextual nuances that shape their understanding.

Interpretivism, as the chosen epistemological stance, values qualitative methods to capture the depth and richness of subjective experiences (Collins, 2018). Through open-ended questions in Survey B, this study aims to uncover the complex layers of meaning attached to BIM within the Libyan AECO sectors and architectural educational context. The research seeks to understand the subjective viewpoints of participants, emphasizing the importance of context, culture, and individual interpretations in shaping their attitudes toward BIM education.

Positivism, as the chosen ontological foundation, claims the existence of an objective reality that can be observed, measured, and analysed (Saunders et al., 2019). In the context of BIM integration, this study treats BIM as an objectively measurable entity with inherent characteristics and functions. It aims to identify and quantify factors contributing to the successful adoption of BIM, emphasizing the objective reality of BIM within the Libyan AECO sectors and its impact on architectural education.

Positivism, with its emphasis on empirical evidence and scientific methods, guides the research toward quantitative approaches (Saunders, 2019). Surveys were utilised to collect data objectively regarding BIM adoption, awareness, and integration. The study seeks to obtain value-free responses from participants, allowing for statistical analysis to identify patterns and correlations related to BIM integration.

This study recognizes the diversity of perspectives and aims to provide a holistic understanding of BIM integration by integrating both interpretivist and positivist elements. By employing a mixed-methods approach, it seeks to triangulate findings, offering a comprehensive and nuanced exploration of the complex dynamics surrounding BIM in architectural education in Libya.

4.2 Research Approach and Design

The research approach serves as a fundamental framework that guides the overall methodology of the study. It outlines the general direction and orientation that the research will take in order to address the research question and objectives effectively (Creswell and Poth, 2016). In this section, the chosen research approach is discussed, focusing on the strategy of inquiry that will be employed to gather and analyse data.

4.2.1 Strategy of Inquiry

The strategy of inquiry represents the main methodological approach used to explore the research problem. It outlines how the researcher plans to engage with the data, generate insights, and draw conclusions. In this study, two key components of the strategy of inquiry are highlighted: (1) deductive and inductive theory and (2) the qualitative and quantitative approaches.

4.2.1.1 Deductive and Inductive

The research approach can be described as the process of establishing theory and argues that it can typically be deductive or inductive. Researchers use the deductive approach to construct a theory, hypothesis, and research strategy for testing the hypothesis (Easterby-Smith et al., 2012; Saunders, 2019). Inductive research collects data and generates a theory according to the outcomes analysis data, and deductive research collects data and establishes a theory accordingly to data analysis (Azungah and Kasmad, 2018). According to Saunders (2019), an inductive approach is related to interpretivism, and a deductive approach is related to positivism.

It is crucial to note that theory is typically attended to and addressed in a deductive approach at the beginning of a research study project. In this regard, the theory must first be defined before any attempts are made to test theoretical reflections. Furthermore, theoretical principles are the driving force behind data handling (Bryman, 2015). On the other hand, an inductive method requires that a research study project be constructed to generate a concept as a result after the completion of the research study. This is because an inductive method generates a concept from the research study. It is essential to keep in mind that this methodology is far more adaptable, and in addition, theoretical conceptions often emerge out of the data that has been improved (Bryman, 2015). There are several differences between inductive and deductive research due to the different procedure flows associated with the two techniques (See **Table 4.1**). These differences can be attributed to inductive and deductive research following two different lines of inquiry. Despite the apparent rigidity of the distinctions between the two ways, most research studies adopt a flexible strategy by combining both methodologies inside the same research study at various stages (Bernard and Bernard, 2013; Lawrence, 2014; Saunders, 2019). In addition, Anderson et al. (2015) recommend that when deciding which of both approaches or the incorporated, is the most appropriate technique to be adopted for the particular research study, it is best to have a consideration into the focus of the research study and the nature of the research study subject. This is because it is best to consider the nature of the research study subject to make the best decision.

Table 4.1: Summary of deductive and inductive

Characteristic	**Deductive**	**Inductive**
Approach	Top-down	Bottom-up
Starting point	Theory	Data
Goal	Test the validity of a theory	Generate new insights and understanding
Advantages	More efficient and more likely to confirm the theory	More flexible, more likely to generate new insights
Disadvantages	It can be challenging to find a relevant theory, which may not be able to explain all the data.	It can be more time-consuming and more difficult to communicate.

This study evaluated two samples of surveys from diverse research contexts using two different instruments:

- Instrument A is used to assess the current state of BIM in the Libyan AECO sectors regarding BIM adoption, awareness, training, and challenges.

- Instrument B is used to evaluate education integration concerns associated with the incorporation of BIM instruction into architectural education in Libyan institutions.

The quantity of existing literature plays a significant role at the outset of any investigation. According to Anderson et al. (2015), a limited number of recognised literature shows that the field has not received enough attention or has yet to be formed, indicating that the inductive technique is the more suitable option. There are even more than enough academic studies documenting the effects of BIM on the AECO sectors. For instance, the nation-level of BIM reports are easily accessible internationally, which helps identify the educational framework that serve as the structure of this study, ultimately leading to the deductive orientation of this research study. However, this is not the case when analysing the impact of BIM on architectural education in Libya. The literature on BIM in AECO sectors and architectural education is limited, and no national degree report exists. It has left the academic sector without considerable support, giving architectural education a great deal of freedom to chart their way toward the cause of BIM. The absence of recognized directions for the application of BIM in teaching and learning has provided even more opportunities for investigation and experimentation, making it more challenging to develop a strict and structured instrument for the purpose of information gathering. A tool with a certain degree of transparency is required to permit comments and perspectives that may surpass the research study's assumptions and theory.

4.2.1.2 Qualitative and Quantitative Approaches

The selection of a research method is an essential step in the research process. In the context of knowledge inquiry, two primary methods are employed: qualitative and quantitative. The quantitative approach emphasizes data quantification, while the qualitative approach focuses on words or pictures during data collection.

To formulate a plan for incorporating BIM into architectural education in Libya, the data collection method has been utilised to collect statistical data, which other results have supported. The quantitative approach becomes critical to better synthesise the study’s aim and objectives, as it allows for direct touch and interaction with Libya’s BIM drivers. A quantitative approach was implemented to synthesise the study’s goals and objectives further, allowing direct contact and interaction with Libyan BIM drivers. Nevertheless, applying quantitative research as an integral methodology broadened the research expertise and grasp of the BIM phenomenon in the academic and workplace. The theoretical rationale for applying quantitative analysis as a supporting method to the primary strategy is built on the survey method sequence (Fombad et al., 2009). This study uses this technique to statistically support the primary qualitative method and develop a stronger academic demand for BIM adoption from the AECO sectors (Ryan and Tilbury, 2013).

However, this method can be used in quantitative research, such as case study research or a mixed-method research design (Saunders, 2019). **Table 4.2** shows distinctions between qualitative and quantitative analysis.

Table 4.2: Comparing quantitative and qualitative research

Aspect	Quantitative research	Qualitative research
Research Focus	Typically, numerical data and statistics	In-depth understanding and insights
Data Collection	Structured surveys and experiments	Unstructured interviews and observations
Sample Size	Large and representative	Small and purposive
Data Analysis	Statistical analysis	Thematic and content analysis
Objectivity	Relative objectivity	Relative subjectivity and researcher involvement
Hypothesis Testing	Hypothesis testing	Exploratory and descriptive
Contextual Understanding	Limited contextual understanding	Rich contextual understanding
Generalizability	High generalizability	Low generalizability
Time and Resources	Usually, efficient	Time and resource-intensive
Theory Development	Often deductive	Often inductive

The implementation of qualitative methods is based on developing qualitative data quality criteria (Bekhet and Zauszniewski, 2012). The AECO sector has a long history of using quantitative methods in research. This is due to the AECO sectors' tendency toward objectivity and positivist research philosophy. However, over the past three decades, there has been a growing recognition that social science differs from natural science and that a more balanced approach is needed. This has led to mixed methods research, which blends qualitative and quantitative elements.

For several reasons, mixed methods research has gained popularity in the AECO sectors and architectural education. First, it allows researchers to gain a deeper understanding of the research topic by collecting data from multiple sources. Second, it can help to address the limitations of both qualitative and quantitative approaches. Third, funding agencies and other stakeholders are more likely to accept it. Despite ongoing debates on methods integration, the number of research articles utilizing mixed methods has consistently increased in the AECO sectors and architectural education. This shows the growing recognition of this approach among researchers today.

This research necessitates data collection methods that yield both breadth and depth to ensure a credible understanding of BIM integration in Libyan architectural education. To achieve this, a mixed-methods approach was employed, incorporating both quantitative and qualitative data collection techniques.

- Quantitative data: The survey employed closed-ended questions to gather statistically significant data on industry expectations regarding BIM skills for graduates and universities' effectiveness in delivering those skills. This approach allowed for a broad and comprehensive data collection process, reaching a large number of participants.

- Qualitative data: The survey also incorporated Open-ended questions to capture qualitative data on participants' experiences and perspectives regarding BIM education. This approach allowed for a more understanding of the challenges and opportunities associated with equipping graduates with industry-ready BIM skills.

BIM technology remains an emerging tool in the Libyan AECO sector and architectural education, with limited expertise and technical skills. Despite these challenges, questionnaire-based surveys, carefully crafted with both closed- and open-ended questions, were chosen as the primary data collection strategy. This approach aimed to achieve a comprehensive understanding by capturing a broad range of data through close-ended questions, and gaining deeper insights through open-ended questions, allowing educators to elaborate on their experiences and perspectives.

4.2.2 Research Design

Mixed methods research is a research methodology that combines quantitative and qualitative research methods to gain a more comprehensive understanding of a research problem. There are six primary mixed methods research designs: (1) convergent parallel design, (2) explanatory sequential design, (3) exploratory sequential design, (4) embedded design quantitative, (5) transformative design, and (6) multiphase design (Creswell, 2013). **Table 4.3** provides a summary description of these methods, which helps to decide which method to choose in this study. This study adopted a convergent parallel design more suitable to the context of architectural education in Libya.

Table 4.3: Summary of six mixed methods research designs

Mixed Methods Research Design	Description	Data Collection Sequence
Convergent parallel design	Simultaneously collect quantitative and qualitative data, with equal emphasis. Afterwards, merge or compare the findings to gain a comprehensive understanding.	Quantitative and qualitative data were collected concurrently.
Explanatory sequential design	Begin with quantitative data collection and analysis. Follow up with qualitative data collection to explain or enrich the quantitative results.	Quantitative data is collected and analysed first, followed by qualitative data collection and analysis.
Exploratory sequential design	Start with qualitative data collection and analysis to explore the research question. Then, use the findings to guide subsequent quantitative data collection.	Qualitative data is collected and analysed first, followed by quantitative data collection and analysis.
Embedded design quantitative	Focus primarily on quantitative data, with qualitative data playing a secondary and supportive role to enrich or explain quantitative results.	Quantitative data collection and analysis with qualitative data incorporated as a supplementary part of the study.

Mixed Methods Research Design	Description	Data Collection Sequence
Transformative design	It aims to create positive change by actively involving participants and stakeholders in the research process. This approach addresses social issues and improves existing conditions.	Mixed data collection with the active involvement of participants and stakeholders throughout the research.
Multiphase design	Involve multiple stages of data collection, including both quantitative and qualitative components. Allows for different methods at various phases.	Multiple phases of data collection, where methods can vary across stages and complement each other.

As Creswell (2013) described, the convergent parallel design is the mixed methods model adopted for this research. This design calls for the independent acquisition of quantitative and qualitative data from two distinct sample sets. The data sets are then independently analysed, and the resulting topic interpretations are subsequently merged.

The primary purpose of the convergent parallel design is to collect separate and complementary data on the same subject, thereby enhancing the overall comprehension of the research topic. This design's ability to generate insights through the investigation of multiple data types is one of its strengths. Additionally, the efficacy of data collection is enhanced due to the concurrent collection of both datasets, which saves time and resources. In addition, by independently analysing each dataset with conventional methods before integrating the results, each data type can be examined thoroughly.

In addition, Creswell (2013) points out, that the convergent parallel design presents several challenges despite its benefits. Merging datasets with differing sample sizes, which can complicate the interpretation of results, is one such obstacle. Moreover, dealing with two sets of vastly distinct data types may necessitate careful consideration to achieve meaningful integration. The potential for contradictory results from different analyses necessitates vigilance during interpretation.

In determining the most appropriate approach for this research, it has become clear that the characteristics of a relatively new mix method are better aligned with the context. The lack of literature evidence in Libya, particularly in the context of architectural education, necessitates the incorporation of inductive reasoning as one of the research instruments. However, the overall scope of this research tends to be objective and positivist from an ontological and epistemological perspective. Therefore, the research strategy must incorporate both quantitative and qualitative approaches. Instrument A employs a quantitative methodology, whereas Instrument B uses mixed methods incorporating quantitative and qualitative elements.

The mixed research approach allows the study to overcome information gaps between industry practitioners and academics, allowing for better BIM integration into architectural education in Libya. In addition, it helps both sides of the industry learn how to work together to achieve global standards. Any new research is always guided by previous research. **Table**

4.4 provides previous research on BIM in education using mixed research methods. These studies help to identify areas of prior scholarship to avoid duplication of effort, position the research within the context of existing literature, point the way to fulfilling a need for additional research, and identify new ways to interpret prior research (Labaree, 2017; Öztürk and Şahin, 2019).

Table 4.4: Previous studies on BIM in education applied a mixed research approach.

No	Author and year	Title	Methodology
1	Casasayas et al., 2021	Integrating BIM in Higher Education Programs: Barriers and Remedial Solutions in Australia	A literature review and interviews were used to identify the barriers
2	Ramadan, 2021	An Approach to Introduce BIM into schools of architecture curriculum in Greater Khartoum	A literature review and interviews were conducted to develop the approach
3	Daoor, 2021	Introduction BIM in Engineering Curriculum: Student Perspectives from Gaza Strip s Universities	Review existing literature and questionnaires to get students' perspectives
4	Adhikari, S Meadati, P Baek et al., 2020	The implementation of BIM application in university teaching	Survey and case study of BIM implementation at the university
5	Li et al., 2020	A review for presenting building information modelling education and research in China	literature review and case studies were used to explore BIM education in China
6	Agirbas, 2020	A questionnaire study was conducted on the student group	A questionnaire was used on the student group with a case study
7	Shibani, Awwad and Ghostin, 2020	Investigating the Barriers to Building Information Modelling (BIM) Implementation in Higher Education in Morocco	This research uses a mixed method approach: questionnaire and interview to identify BIM education challenges
8	Olugboyega and Windapo, 2019	Framework for integrating BIM education in the curriculum of AECO programs	A qualitative approach was used in this investigation
9	Lee, Lee and Ahn, 2019	Sustainable BIM for Construction Engineering Education Curriculum for Practice-Oriented Training	This study used a literature review and an interview
10	Boton, Forgues and Halin, 2018a	A framework for building information modelling implementation in engineering education	literature review and case study, the methodology was used to develop and validate the framework
11	Krivonogov et al., 2018	Implementation of BIM technologies in architectural educational programme	A literature review was used in this investigation
12	Huang, 2018	BIM in architecture curriculum: a case study	A case study methodology was used to evaluate the BIM course
13	Belayutham, Zabidin and Ibrahim, 2018	Dynamic Representation of Barriers to Adopting BIM in Malaysian Tertiary Education	This study used qualitative and quantitative approaches

4.3 Research Technique

Research technique is an essential component of the research process, consisting of the methodologies and strategies used to collect data or information for an investigation. Choosing a suitable research technique is crucial because it directly affects the research results' quality, dependability, and conclusiveness (Bryman, 2016). There are two types of data sources: primary and secondary. Researchers must choose between using primary and secondary data. Researchers can collect primary data for specific research purposes using interviews, questionnaires, experiments, and observation. Due to its limited view, it can be resource-intensive and biased, despite providing unique and context-specific insights. In contrast, secondary data already exists and consists of sources such as articles, books, and government reports. It is cost-effective, allows for historical comparisons and large-scale analyses, and lacks specificity.

Research objectives, available resources, and time constraints influence the choice between primary and secondary data. Each method has advantages and disadvantages, which are summarised in **Table 4.5**, and researchers must evaluate them thoroughly. Preliminary data permits customised data collection and a more profound comprehension, but they can be time-consuming and subject to bias. Secondary data is accessible and cost-effective, but relevance, accuracy, and reliability may pose challenges (Creswell, 2013; Saunders, 2019).

Table 4.5: Comparison of research techniques: advantages and disadvantages

Research Technique	**Advantages**	**Disadvantages**
Secondary Sourced Data		
Newspapers, Articles, Books, Reports Literature documents	- Rich, in-depth insights - Generating new hypotheses. - Precise & measurable data - Enables comparisons. - Objective & replicable findings - Cost-effective	- Subjective & biased - Non-representative samples - Time-consuming - Oversimplification - Outdated data - Ethical concerns
Primary Sourced Data		
Closed-ended questionnaires	- Easy to answer, - Easy analysis, - Allows comparison	- No room for explanations, - Limited depth, - Participant disagreement, - Generates only quantitative data
Open-ended questionnaires	- Participants express freely, - Rich and detailed data, - Diverse viewpoints	- Different opinions may lead to confusion, - Potential varied interpretations
Structured interviews	- Questions explained, - Reliable data, - Uniform answers	- Limited probing, - Challenging to convert to data, - Less richness than in open-ended
Unstructured interviews	- Allows open discussion, - Valid data, - Flexible questions, - Diverse viewpoints	- Time-consuming, - inconsistency between interviews, - Difficult analysis, - Hard to replicate

Research Technique	Advantages	Disadvantages
Self-completion questionnaires	- Inexpensive, - Convenient, - Large data output, - Less bias	- Low response rate, - Limited representativeness, - Unclear identification, - no follow-up
Observation	- Increases awareness, - Useful in own organizations	- Time-consuming, - Ethical dilemmas, - Difficult data recording
Focus groups	- Stimulates group discussion, - Diverse perspectives	- Moderation challenges, - Dominant participants, - social desirability bias
Case studies	- Provides comprehensive insights, - Suitable for specific contexts	- Limited availability, - Lacks certain information
Pilot studies	- Provides insight, - Enhances accuracy, - Prepares for future research	- Requires significant preparation and time

In the context of the preceding **Table 4.5**, the research employs a survey as the primary research method for this study, given its effectiveness in assessing the statistical relationship between BIM competencies needed by the industry and the outcomes of universities. Surveys were chosen because they could reach many participants, allowing for a broader and more comprehensive data collection process.

This research utilizes a mixed methods approach for data collection. While a survey serves as the primary quantitative data collection tool, the study also incorporates qualitative elements by using open-end questions in order to gain a deeper understanding of the relationship between BIM skills needed by the industry and the outcomes of universities.

The next section will detail research techniques strategically employed in the four distinct phases of the study. These techniques will be explained in the context of their specific relevance within each research phase

4.4 Phases of Research Technique Implementation

This research continues by employing various tactics utilised in the four phases: planning, process, development, and outcomes. These research techniques possess unique attributes but also exhibit interconnections with each other, as demonstrated in **Table 4.6**. This chapter describes every technique and supports the research's stages. This section discusses these strategies in relation to the present study.

Table 4.6: Research techniques employed in each stage of the study.

Research Phases	Research Techniques	Data Type
Research Planning	- Literature review - Quality comparative analysis	Secondary sources
Research Process	- Data collection Surveys - Data analysis Descriptive statistics	Primary sources
Research Development	- Framework development - Framework assessment	Primary and secondary sources
Research Outcomes	- Finalised the framework	Primary and secondary sources

4.4.1 Phase 1: Research Planning.

This phase is primarily concerned with planning and designing the research study. The two research techniques applied in this phase are:

4.4.1.1 Literature Review

This phase begins with a literature review of several matters connected with the current study. The literature review presents and critically analyses the state of knowledge in the topic area at the time of the evaluation (Denney and Tewksbury, 2013). To help guide the research question and objectives, Creswell (2013) states that quantitative research generally begins with a large body of literature introducing difficulties or topics connected to the topic's context. In this PhD study, the literature review discusses the rise of new digital technologies with more focus on the use of BIM technology in the AECO sectors internationally and in the study area (Libya). As a result, this provides an understanding of existing concerns, including the challenges relevant to BIM implementation in the AECO sectors, most notably the lack of training, qualified personnel, and experience required to apply the technology entirely. In addition, the literature discusses the importance of architectural education to offer industry graduates the necessary AECO knowledge and skills related to BIM. The key to ensuring that this is accomplished is the development of a BIM programme that meets industry requirements, ultimately formulating research questions. The literature review presented in Chapter 2 has extended the study by underlining the difficulty of incorporating BIM into the existing full curriculum and the impact of the research shortage on BIM acceptance in architectural education. The literature reviews are reviewed, referenced, and utilised towards the conclusion of this research, notably in Chapter 9, to evaluate, compare, justify, and make logical sense that supports the current research findings. This procedure demonstrates the positivist logic of the study, in which the literature is employed deductively to frame the research questions.

A systematic evaluation of the existing literature is achieved by reviewing over 335 articles. The review was started by creating a list of criteria associated with the research topic and aimed to make the selection of documents concerning "Building Information Modelling" (BIM), 'BIM adoption,' 'BIM barriers,' 'BIM education,' 'BIM curriculum,' 'BIM courses,' and 'BIM teaching.' After that, data collection was conducted from different sources to ensure that the most appropriate and reliable evidence is drawn from books, articles, and reports, which could be made by using online research repositories, including Google Scholar, Science Direct, Web of Science, and other relevant databases available at the University of Strathclyde library.

4.4.1.2 Qualitative Comparative Analysis

The researcher employed qualitative comparative analysis (QCA) in Chapter 2 to evaluate and examine global approaches to integrating BIM into the architectural curriculum. This method was increasingly used in education research (Cilesiz and Greckhamer, 2020), as it was utilised to describe as many BIM practices in education as possible. The documents were divided into two groups to create relationships and patterns between diverse theme areas based on similar entities. The first group includes all sources that discuss BIM: adoption, awareness, maturity levels, benefits, and barriers in the AECO sectors, which provided the holistic background to the research and assistance in understanding the status of BIM implementation around the world (See **Annex 1** which includes sources reviewed in Group 1). The second group contains all resources that discuss integrating BIM into education (See **Annex 2**, which consists of sources reviewed in Group 2). A crucial literature review was undertaken to analyse and discuss data to gain a holistic understanding of the research area. More crucially, the research problems are enhanced, and the study purpose and objectives are defined. The literature review discussed the theoretical and basic concepts behind developing strategic integration and curriculum frameworks. The researcher highlighted the best possible examples and repeated practice by using QCA to decide on the most common BIM in education procedures.

4.4.2 Phase 2: Research Process

The research process phase involves collecting and analysis the data from two different groups: professionals and educators in the Libyan AECO sectors and architectural education. This phase has been achieved in two stages.

4.4.2.1 Stage 1: Data Collection

In this stage, data collection techniques are employed to gather primary data directly from the research subjects. The techniques used in this stage are:

Survey Overview

The present research commenced with a review of existing literature and a QCA using secondary data to gain a holistic understanding of the subject matter. This step aimed to identify related issues and formulate a research framework within the context of the study. Subsequently, the research question was formulated based on the established framework. To address this research question effectively, primary data collection became imperative. This research aims to develop a strategic educational framework and a full curriculum module for integrating BIM into architectural education, aligning it with industry requirements.

Among the various methods available for gathering primary data in education research, survey research is one of the most established and widely utilised approaches (Creswell, 2013; Bryman, 2015). **Table 4.7** presents the survey's advantages and some limitations. For this study, self-completed questionnaires were selected due to their cost-effectiveness, potential for accurate and precise data, suitability for statistical analysis, ability to reach a large population, and ease of data collection.

Table 4.7: Advantages and disadvantages of questionnaire-based survey

Advantages	Disadvantages
- Cost-effectiveness - Accurate and precise results - High statistical significance - Represents a large population. - Convenient data collection	- Limited flexibility in design - Potential issues with question appropriateness - Less suitable for exploring controversial subjects

This research prioritizes a comprehensive understanding of the status of BIM within the AECO sectors and architectural education in Libya. Recognizing the need for diverse perspectives on BIM adoption beyond specific organizations or individuals, the study adopted a mixed-methods approach. The primary tool utilized was a questionnaire-based survey that incorporated both closed-ended and open-ended questions, enabling participants to share their thoughts and experiences in detail. This approach choice proved particularly crucial in 2021, a year marked by the disruptions of the COVID-19 pandemic. The pandemic posed significant challenges, including restricted mobility and limited internet access in Libya, making online interviews impractical. However, the inclusion of open-ended questions in the survey allowed participants to provide rich, detailed responses in their own words despite these limitations.

The study targeted Libyan AECO professionals and architectural educators through two surveys:

- Survey A with AECO professionals: Utilising closed-ended questions, this survey gathered quantitative data from industry practitioners. It aimed to provide a statistically significant overview of industry perspectives on BIM adoption, importance, challenges, and the role of architectural education in equipping graduates with BIM knowledge and skills.
- Survey B with architectural educators: Utilising both closed-ended and open-ended questions, this survey gathered quantitative and qualitative data from Libyan architectural educators. This approach allowed for efficient data collection on various aspects of BIM: awareness, teaching strategies, academic levels of BIM integration, responsibility, challenges, and architectural education readiness.

The next subsections provide more details about the design of Survey A and Survey B, including the types of questions used, and the sampling technique employed to ensure a representative sample of the target populations.

The Design of Survey A

Survey A is a structured questionnaire designed to collect data on professionals' experiences, awareness, utilisation of BIM, and their organisations' practices concerning BIM adoption and training. The survey aims to achieve a representation of Libyan professionals in the AECO practices.

The survey is based on a positivist philosophical stance, emphasising a direct, objective, impartial, and quantitative approach. The survey has been developed based on an extensive literature review. **Annex 1** includes resources used to develop the survey. Survey A comprises 23 close-ended questions, categorised into seven parts, as illustrated in **Table 4.8**. The chosen question types facilitate standardised responses, enabling straightforward data analysis and trend identification. Multiple-choice questions and checkboxes provide flexibility in capturing technology usage and the varied tasks supported by BIM-related applications. In addition, 5-point Likert scale questions quantitatively measure attitudes and opinions, enhancing the understanding of professionals' perspectives on BIM. This mixed-method approach assesses professionals' experiences, awareness, utilisation, and training needs.

The survey is a valuable tool for understanding the current state of BIM adoption in the Libyan AECO sector and identifying areas where improvements can be made. The survey results have been used to develop a BIM excellence framework for the architectural education domain, with a focus on professionals’ expectations regarding BIM education.

Table 4.8: Survey A parts, aims and questions types

Part	Aim	Question Types
Part 1: General Information	Collect basic demographic information about participants who are professionals in the construction industry.	Multiple-choice questions
Part 2: Organizational Activities	Explore types of construction-related activities and organizational characteristics in respondents' workplaces.	Multiple-choice questions
Part 3: The Use of Digital Technologies	Assess current usage of digital technologies, including BIM-related applications, in professionals' daily work.	Multiple-choice and checkboxes
Part 4: Awareness and Adoption of BIM	Gauge professionals' awareness of BIM and its adoption within their organisations.	Multiple-choice and Likert scale questions
Part 5: Training and Resources for BIM	Explore availability and demand for BIM training and specialized professionals within organizations.	Multiple-choice questions and checkboxes

Part	Aim	Question Types
Part 6: Barriers and Key Drivers of BIM	Identify the main barriers and key drivers influencing BIM adoption within organizations.	Multiple-choice and Likert scale questions
Part 7: Professionals' Expectations Regarding BIM Education	Discern perspectives on critical aspects of BIM education for architectural education.	Multiple-choice and Likert scale questions

The Design of Survey B

Survey B is a structured questionnaire designed to collect data from Libyan architectural educators on BIM integration with undergraduate architectural education. The survey employs a mixed-methods approach, combining closed-ended and open-ended questions. This allows for a better assessment of educators' experiences, awareness, utilisation, and training needs, and identifies teaching and learning strategic. The survey B is theoretically grounded in two well-known frameworks:

- TPACK Framework (Technological Pedagogical Content Knowledge): This framework helps to understand how educators combine knowledge of BIM technology (Technological Knowledge), effective teaching approaches (Pedagogical Knowledge), and architectural content (Content Knowledge) to integrate BIM effectively.
- CDIO Approach (Conceive, Design, Implement, Operate): This framework aligns with the hands-on nature of BIM and architectural education. By assessing educators' familiarity with the CDIO approach, it helps to gain insights into their readiness to incorporate practical BIM tasks into the curriculum.

The questionnaire consists of 23 questions, organised into five parts. **Table 4.9** illustrates the Survey B parts regarding its aim and question types. The closed-ended questions are used to gather demographic data, and assess the usage of digital technologies, including BIM-related applications. The 5-point Likert scale is utilised to evaluate respondents' attitudes and opinions regarding various aspects of BIM, such as awareness, adoption, importance, responsibility, and challenges. The open-ended questions are strategically incorporated into the survey to elicit detailed, qualitative participant responses. These questions encourage respondents to freely express their thoughts, ideas, and suggestions without being confined to predefined options. By doing so, the survey seeks to capture academics' perspectives on teaching and learning strategies for BIM education, potential programmatic changes, and the requirement for support.

The choice of mixed question types facilitates standardised responses, thus simplifying data analysis and trend identification. Multiple-choice questions and checkboxes offer flexibility in capturing technology usage and the diverse tasks BIM-related applications support. Meanwhile, Likert scale questions provide a quantitative measure of attitudes and opinions, further enhancing the comprehension of professionals' viewpoints on BIM integration.

Table 4.9: Survey B parts, aims and question type

Parts	Aim	Question Types
Part 1: General Information	Collect basic demographic information about survey participants, specifically age, teaching experience, academic qualifications, current academic position, university, and department.	Multiple-choice questions
Part 2: The Use of Digital Technologies	Investigate the use of digital technologies in the architectural program, focusing on the tools taught and their primary purposes.	Multiple-choice questions
Part 3: BIM Awareness, Importance, and Responsibility	Gauge respondents' awareness and perception of BIM in architectural education. Explore views on the importance of BIM and responsibilities related to its integration.	Likert scale, multiple-choice, and open-ended questions
Part 4: Teaching and Learning Strategies for BIM Education	Explore strategies and challenges related to BIM integration in architectural programs. Understand respondents' perspectives on implementing BIM-related changes.	Multiple-choice and open-ended questions
Part 5: University Readiness and Challenges for BIM Education	Assess universities' readiness for BIM integration in educational programs. Identify challenges that might be encountered.	Multiple-choice, Likert scale, and open-ended questions

Sampling Technique

Surveys play a crucial role in gathering data from populations of interest. However, due to scale, time constraints, and limited resources, surveying the entire population may not always be feasible or practical (Creswell, 2018; Dillman et al., 2014). This study utilised two separate surveys. Surveys A with professionals in the AECO sectors and Survey B with educators from architectural schools in Libya. The following subsections discuss the sampling methods adopted for each survey, highlighting the importance of sampling in obtaining reliable and relevant data.

Sampling Technique for Survey A

The sampling approach used for Survey A aimed to achieve a various and representative sample of Libyan professionals involved in the AECO sectors, particularly those with experience in architectural practice and BIM implementation. Due to the limited access to a comprehensive sampling frame of all professionals, a combination of probability and non-probability sampling techniques was employed (Wiśniowski et al., 2020).

Probability sampling was implemented through the manual entry method, where the researcher directly visited local architectural and construction firms of various sizes. While not completely random due to the targeted selection of firms (Taherdoost, 2016), it ensured a geographically varied sample and included smaller firms not as active on social media.

Non-Probability sampling was used through social networks (ResearchGate, LinkedIn, Facebook, and WhatsApp) and email invitations. This approach relied on the researcher's existing network and readily and easily available online platforms, potentially leading the sample towards individuals more active on social media or with prior research connections.

A total of 174 respondents had completed the survey, with the following breakdown by distribution method:

- Manual entry: 124 respondents, primarily gathered by the researcher's visits to local architecture and construction firms of various sizes in Libya.
- Social Networks: 35 respondents were distributed through communication apps like ResearchGate, LinkedIn, Facebook, and WhatsApp by sharing the questionnaire link or form.
- Email invitation: 15 respondents, involving the sending of emails to 25 Libyan professionals with research information.

The mixed approach was adopted due to the lack of a comprehensive sampling frame as a complete list of all relevant professionals in Libya was unavailable, making random sampling difficult. In addition, accessibility challenges as reaching professionals in remote areas or smaller firms through email or social media might be less effective. The combination of methods aimed to balance representativeness with feasibility, capturing a wider range of professionals while acknowledging the potential for bias (Vehovar, 2016).

Sampling Technique for Survey B:

The sampling approach employed in Survey B aimed to achieve a representative sample of Libyan university educators in the field of architectural. Surveying the entire population of a target group can be impractical, and time-consuming, particularly for large or geographically dispersed populations (Creswell, 2018; Dillman et al., 2014). However, Survey B employed a targeted sampling approach focused exclusively on public architectural schools in Libya. This decision was driven based on two factors:

- Accessibility: Obtaining data from government-affiliated institutions is often more efficient and standardized compared to private institutions.
- Relevance: Public architectural schools play a significant role in shaping the future of Libyan architectural education and practice.

Within this targeted focus, two contrasting methods were employed to address specific limitations:

Probability Sampling: This was implemented through manual entry, where the researcher directly visited local architectural schools of varying sizes. While not completely random due to the targeted selection of schools (Taherdoost, 2016), this method ensured a geographically diverse sample and included some educators not active on social media.

Non-Probability Sampling: This involved social networks (ResearchGate, LinkedIn, Facebook, and WhatsApp) and email invitations, leveraging the researcher's existing network and readily available online platforms. This approach, however, could potentially skew the sample towards individuals more active on social media or with prior research connections.

A total of 227 respondents had completed the survey, with the following breakdown by distribution method:

- Manual entry: 158 respondents, primarily gathered by the researcher's visits to local architectural schools to collect data.
- Social Networks: 45 respondents, distributed through communication apps like ResearchGate, LinkedIn, Facebook, and WhatsApp by sharing the questionnaire link.
- Email invitation: 22 respondents, sending emails to 35 Libyan educators in architectural education with research information.

Each method addressed the specific limitations of the others. Purposive sampling ensured relevance, convenience sampling broadened geographical reach, and snowball sampling increased the potential response rate and captured diverse perspectives. This mixed approach aimed to strike a balance between representativeness and feasibility, maximizing the generalizability of findings within the context of Libyan architectural education.

4.4.2.2 Stage 2: Data Analysis

Analysing the data is essential to any study because it helps explore acquired data and draw findings (Creswell et al., 2007). The data analysis procedure for both surveys include mainly two steps: (1) Collecting and preparing data and (2) Describing data (or Descriptive Statistics).

Step 1: Data Collection and Preparation

In this step, the data collected from both surveys are organized and prepared for analysis. The data collection methods for both surveys included email invitations, social networks (such as ResearchGate, LinkedIn, Facebook, and WhatsApp), and manual entry. The respondents were professionals in the Libyan AECO sectors for Survey A and academics working in Libyan higher education institutions, particularly in architectural schools, for Survey B.

To ensure data accuracy and accessibility, the researchers used a structured classified database created with Microsoft Excel Access to log and trace the questionnaire responses. This database allowed easy access to recorded data and results, preserving the original records for a reasonable time. By maintaining the original documents from which the data was collected, the researchers ensured cost-effective tracking of data analysis results.

Step 2: Descriptive Analysis

Descriptive statistics is an essential technique used to summarise and describe the fundamental characteristics of the collected data. The researcher employed descriptive statistics to gain insights into the data and draw meaningful conclusions. This step involves providing essential descriptive summaries for each sample, facilitating the development of visual analysis and calculations to make the data understandable.

The researcher used straightforward statistical techniques for both surveys to describe the data: percentage and frequency. These techniques allowed them to examine the data's spread, central values, and variations. Additionally, Survey B contained open-ended questions. To analyse the responses to these questions, a coding process was employed. The responses were coded into separate themes using a coding structure or checklist. This coding method, specifically descriptive coding, allowed the researchers to create summary summaries of all the open-ended responses objectively.

4.4.3 Phase 3: Research Development

The research development phase involves two stages in order to establish a comprehensive framework that encompasses all the requirements for integrating BIM into architectural education and connects BIM education to other relevant disciplines. These stages are framework development and framework assessment:

Stage 1: Framework Development

After completing the data collection and initial analysis phases, the study moves into the crucial stage of analysing the findings and developing a comprehensive BIMEXAE framework. This phase involves synthesizing the information gathered from the literature review, qualitative comparative analysis, and the data collected through surveys A and B to establish a strategic framework for integrating BIM into architectural education in Libya.

The framework development involves designing a structured plan or model that outlines the key components, processes, and guidelines for integrating BIM into architectural education. This is a critical step in addressing the challenges identified in the literature review and aligning the educational curriculum with industry requirements.

The researcher utilizes primary sources, such as the data collected through surveys A and B from professionals and educators, to understand the current state of BIM adoption, the challenges faced, and the specific needs of both the industry and educational institutions. These primary sources contribute real-world perspectives, ensuring the framework is grounded in the actual experiences and requirements of stakeholders.

Secondary sources, including literature on best practices, existing frameworks, and academic research, are also crucial in informing the development process. Insights from secondary sources help in identifying proven strategies, theoretical foundations, and successful models that can be integrated into the proposed framework. By drawing on a diverse range of secondary sources, the researcher ensures that the framework is not only practical but also well-supported by existing knowledge in the field.

Stage 2: Framework Assessment

The assessment stage is designed to refine and assess the proposed framework through consultations with architectural educators. This phase involves the design and implementation of Survey C, which targets educators in Libyan architectural education. The primary sources utilized in this phase contribute to the finalization and assessment of the BIMEXAE framework.

Survey C is designed to gather feedback on the proposed framework from Libyan architectural educators, and other relevant stakeholders. The design of Survey C is informed by the insights obtained in the previous surveys (Survey A and Survey B) and aims to assess the key components of the proposed framework. The survey includes questions that seek opinions on the feasibility, relevance, and effectiveness of the proposed strategies for integrating BIM into architectural education.

Once the data from Survey C is collected, it undergoes a detailed analysis. This analysis involves both qualitative and quantitative methods to extract valuable insights and patterns from the responses. The primary sources here are the opinions and feedback provided by the survey participants, which serve as critical input for refining the framework.

Based on the findings from Survey C analysis, adjustments and enhancements are made to the initial framework. The final framework development incorporates the assessed strategies, addresses any concerns raised by stakeholders, and ensures that the proposed model is strong and applicable in diverse contexts. The primary sources, in this case, are the collective inputs from professionals and educators who have directly contributed to the refinement of the framework through their survey responses.

4.4.4 Phase 4: Research Outcomes

The final phase of the research includes two essential components: framework development and conclusion and recommendations. The framework development process iteratively refines and improves the previously assessed framework. This phase ensures that the final framework is exhaustive, applicable, and relevant to the architectural education context in Libya. The conclusion and recommendations section provides a concise summary of the research outcomes and a synthesis of the previous stages' findings. In addition, it provides specific recommendations for stakeholders in architectural education, policymakers, and institutions to improve BIM adoption and education in Libya.

4.5 Ethical Considerations

Individual or organisations' participation in research creates significant ethical, legal, social, and political considerations. Quantitative and qualitative research requires ethical considerations at personal and societal levels. Participants in quantitative and qualitative research must be informed and ensured of their privacy, anonymity, and confidentiality (Munhall, 2018). Thus, The University of Strathclyde is committed to good research practice, including independent ethical review of all relevant research. The University's Senate Committee must approve the project before beginning any investigation involving a survey or related subjects.

Thus, when performing this research, the researcher examined several ethical issues to ensure the rights of all research participants. The fundamental concept for voluntary participation is to ensure that no one is forced into participating in the research; all participants are fully informed about the research processes and goals. The researcher has also reviewed the terms and conditions of the participants, institutions, and organisations to ensure their confidentiality, anonymity, and privacy. The researcher has also examined and agreed to the University of Strathclyde's research procedures to ensure all relevant ethical problems are considered while developing research plans and executing data collection methods.

4.6 Summary

This chapter explores research methods and paradigms employed to establish the study's foundations. It discusses various research methodologies and data collection strategies for obtaining primary data and achieving its objectives. A central theme is establishing coherence among selected approaches and paradigms, enhancing study strength. Subsequent chapters build upon this groundwork, presenting analyses of previous studies and survey data. This chapter offers an overview of the research methodology, including the research philosophy and adopted approach. The research design, particularly the convergent parallel design, is thoroughly explained. The research techniques for data gathering are carefully examined through the research implementation phases, providing a comprehensive understanding of the research process.

Chapter 5: BIM Practice in Libya

This chapter aims to present the findings from questionnaire-based Survey A (See a copy of the questionnaire in **Annex 3**) which was conducted with Libyan professionals to establish the status of BIM and its implementation in architectural practice. The chapter provides a discussion including (1) Questionnaire-based Survey A, (2) sampling approach, (3) questionnaire design, (4) considerations, and (5) data analysis process. Finally, report the findings.

5.1 Questionnaire-Based Survey A

Survey A was created and distributed to Libyan professionals to obtain their attitudes toward BIM and best practices upon its adoption and implementation in AECO sectors. The surveys sought information on whether or not architectural and construction firms used BIM and, if so, how it was done in order to identify the current status of BIM in the Libyan AECO sectors and identify barriers and the key factors for BIM adoption and also identify how companies train their staff on BIM. This survey also asked professionals about their expectations about how BIM education should be integrated with architectural education.

Survey A was distributed using email invitations, social networks (Facebook and LinkedIn), and manual entry. Survey A was conducted from 10th April to 10th July 2021, a duration of three months. A total of 174 respondents had completed the survey, with the following breakdown by distribution method.

- Manual entry: 124 respondents, primarily gathered by the researcher's visits to local architecture and construction firms of various sizes in Libya.
- Social Networks: 35 respondents were distributed through communication apps like ResearchGate, LinkedIn, Facebook, and WhatsApp by sharing the questionnaire link or form.
- Email invitation: 15 respondents, involving the sending of emails to 25 Libyan professionals with research information.

5.2 Sampling Approach

As discussed in **Section 4.4.2**, on Sampling Techniques for Survey A, surveying the entire population of Libyan AECO sectors is often impractical, and time-consuming. In order to gather representative insights on architecture and BIM, Survey A adopted a balanced approach, combining probability sampling and non-probability sampling due to the lack of a comprehensive sampling frame as a complete list of all relevant professionals in Libya was unavailable, making random sampling difficult.

5.3 The Design of Survey A

Survey A demanded quantitative data from the respective respondents. This is a self-completion survey that was developed by using Microsoft Word and an online tool. The questionnaire had 23 close-ended questions grouped into the following seven parts.

- Part 1: General Information. This aimed to collect data about responders: age, year of experience, qualification, occupation, and sector types.
- Part 2: Organisation Activities. This requires information regarding the type of construction operation, size of delivered projects, and number of employees.
- Part 3: The Use of Digital Technologies. This aims to identify applications used in the presented projects and understand the primary purpose of adopting these tools.
- Part 4: Awareness and adoption of BIM. This aims to determine the extent of BIM awareness among Libyan professionals, know how they get BIM knowledge, the current state and plan of using BIM in the respondent's organisation, and evaluate the importance of BIM to the AECO sectors.
- Part 5: Training and Resources for BIM. This looks to the support training and materials, the need for BIM specialised from organizations to lead BIM implementation and identify the best way for employees to learn BIM.
- Part 6: Barriers and Key Drivers of BIM Adoption. This aims to discover the main barriers and the key drivers of BIM adoption.
- Part 7: Professionals' Expectations Regarding BIM Education. This aims to obtain the professional's expectations in relation to the importance of BIM education, curriculum design and the importance of academic and professional parentships.

5.4 Considerations

The Candidate employed a rigorous design process to minimize bias and optimize the survey for professionals. The structure was carefully designed to be concise and user-friendly, promoting high participation rates. To ensure its effectiveness, the survey underwent a series of pilot studies with two distinct target audiences:

- Academic Review: 6 PhD students from the University of Strathclyde offered feedback on question clarity, potential biases, and overall survey structure.
- Industry Professionals: A group of 4 professionals from the AECO sector in Libya provided valuable insights into the real-world application of the survey within the target industry.

Based on the pilot studies, the Candidate refined the survey in several ways. The order and type of questions were optimized for improved flow and clarity. The visual presentation was enhanced to create a more user-friendly experience. Clear and concise language tailored to the target audience was used throughout. Questions were reframed to eliminate ambiguity and potential leading biases. Additionally, the response choices were adjusted to ensure they adequately captured the range of potential viewpoints. These refinements significantly improved the survey's effectiveness, making it more accessible and reliable for participants, ultimately leading to more accurate and valuable data collection.

5.5 Data Analysis for Survey A

The data analysis phase in the context of Survey A is an imperative element within the research effort. Two discrete stages delineate it: (1) data preparation and (2) descriptive statistics. These stages play a fundamental role in extracting substantively meaningful insights and formulating empirically sound conclusions. These stages must be executed to uphold the research's integrity, ensuring the veracity and credibility of the findings generated therein.

5.5.1 Data Preparation

This stage aims to organise the data for analysis. Therefore, the researcher prepared the data by checking, logging, and tracing the responses to the questionnaire. The candidate constructed a structured classified database using Microsoft Excel to record incoming data, allowing access to inspect the recorded data and outstanding data results at any moment. This also preserved the original data records for a reasonable time, providing the cost-effective benefit of tracking data analysis results back to the original documents on which the data were collected.

5.5.2 Descriptive Statistics

This stage aims to describe and explain the collected data's fundamental characteristics. The candidate sought to provide essential descriptive summaries for each sample to deconstruct the data and facilitate the process of developing visual analysis and calculation to describe the data in a comprehensible manner and make conclusions that summarize a given data set. The candidate sought to provide descriptive elaboration, graphic analysis, and calculations for each question and sub-question to provide the data in a more understandable format. After ensuring all data were distributed in the most appropriate form and description. The survey is statistically analysed using frequency distribution analysis, and their results are presented in the following section.

5.6 Results From Survey A

This section provides an analysis and discussion of data and results from Survey A that have been collected. Data were statistically analysed using frequency distribution analysis, and survey results are presented and discussed in seven parts in this section.

5.6.1 Part 1: General Information

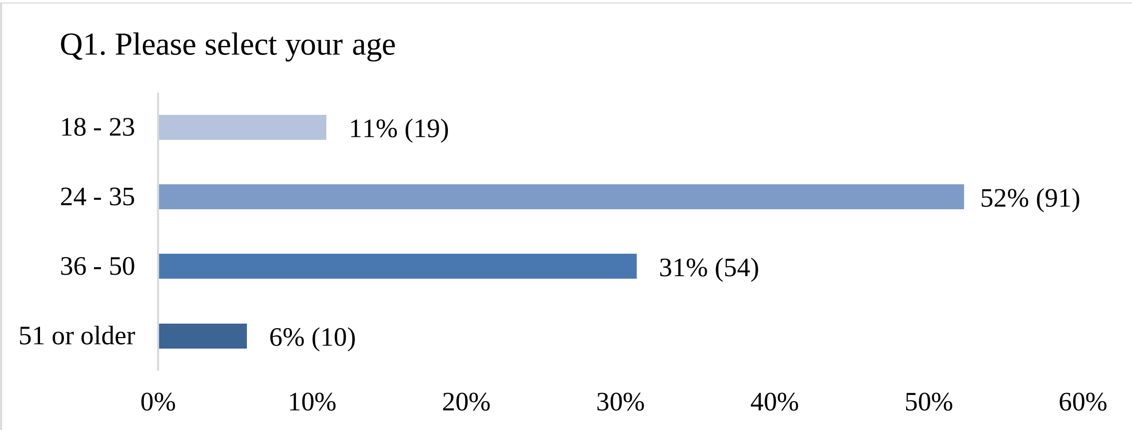

Figure 5.1: Age distribution of participants in Survey A.

Age (Q1). In the first question of Survey A, respondents were asked to indicate their age group. **Figure 5.1** shows that most respondents (52%, N=91) were young professionals aged 24-35. Participants in the 36-50 age group represented 31% (N=54) of respondents, while a smaller percentage 11% (N=19) were aged 18-23. Only 6% (N=10) of respondents were 51 years or older.

This age profile highlights the predominance of young adult participants between 24 to 35 years old. Their perspectives and responses can be valued in implementing emerging technologies such as BIM, given their potential openness to innovation and adaptation of new tools and concepts.

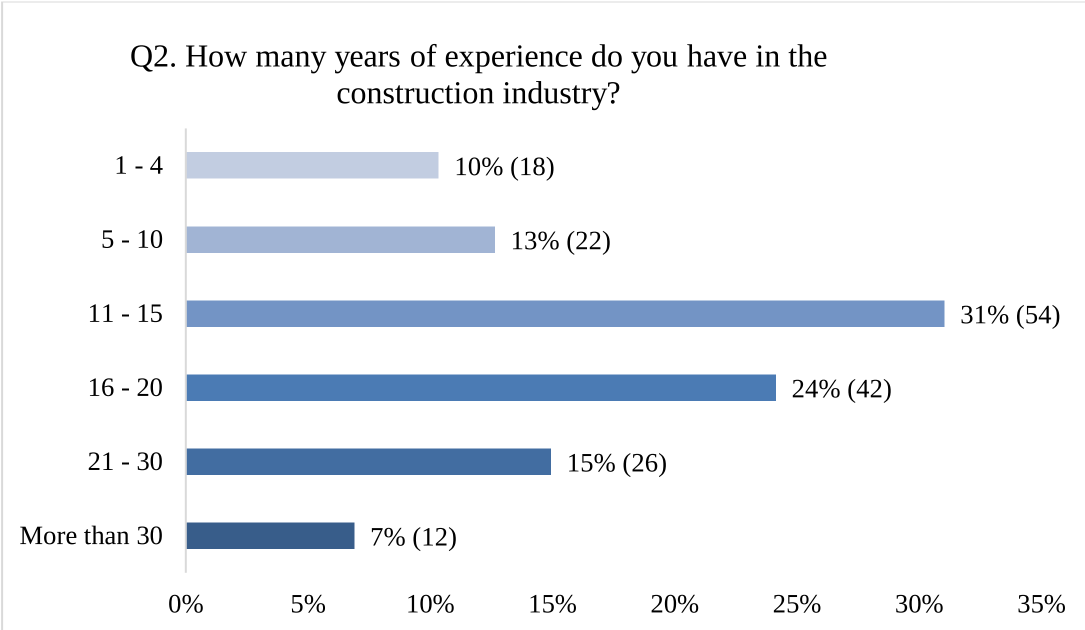

Figure 5.2: Year of experience of participants in Survey A.

Experiences (Q2). **Figure 5.2** shows the years of experience of the participants in Survey A. A substantial number of respondents 31% (N=54) have worked in the Libyan AECO sectors for 11-15 years. Additionally, 24% (N=42) of respondents reported having 16-20 years of experience, and 15% (N=26) stated that they had accumulated 21-30 years of experience within the sector. Respondents with 5-10 years of experience accounted for 13% (N=22), and 10% (N=18) had 1-4 years of experience. Only 7% (N=12) of respondents indicated having worked in the AECO sectors for more than 30 years.

These findings show a significant number of participants with extensive experience in the Libyan AECO sectors. Their years of expertise likely contribute to their ability to adapt and incorporate new technologies, such as BIM, into their projects during the design and construction phases. Their perspectives are valuable in discussions regarding adopting and implementing emerging technologies like BIM within the AECO practices and education.

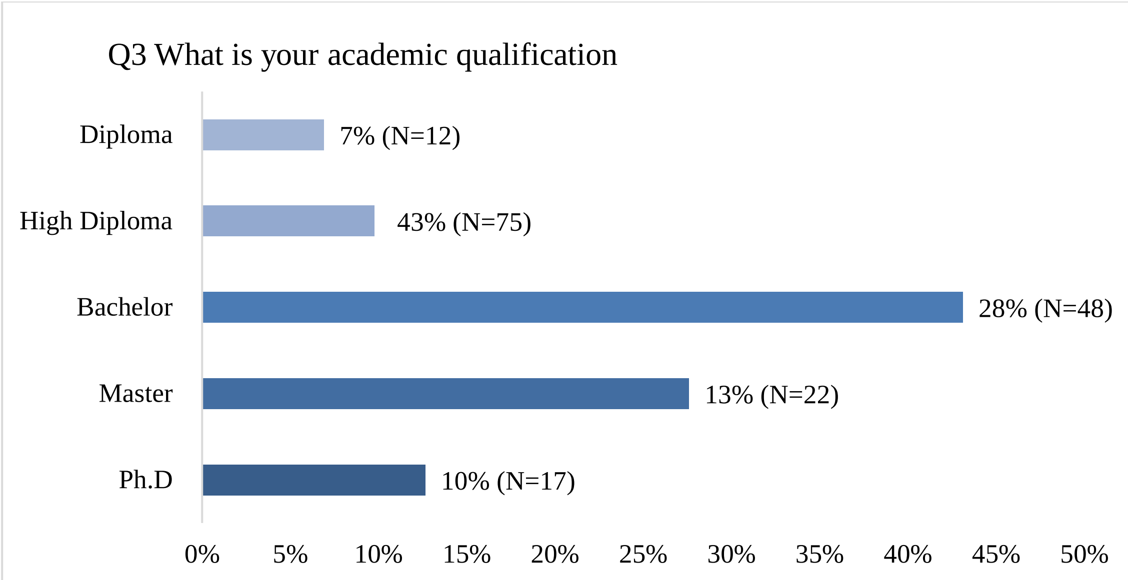

Figure 5.3: Qualification of participants in Survey A

Qualifications (Q3). **Figure 5.3** shows the distribution of qualifications among Survey A respondents. A significant number of respondents (43%, N=75) reported having a bachelor's degree as their highest qualification. This highlights the importance of a strong foundation in engineering principles and practices for professionals in the Libyan AECO sectors. Additionally, 28% (N=48) of respondents held master's degrees, and 13% (N=22) had achieved the highest academic qualification of a PhD. 10% (N=17) of respondents had graduated with a higher diploma, and 7% (N=12) had obtained a diploma as their highest qualification.

These findings show that the distribution of qualifications among the survey respondents reflects a dynamic and diverse educational background within the Libyan AECO professionals. This variety contributes to the value of perspectives and skills within the workforce, potentially enhancing adaptability and innovation within the sector.

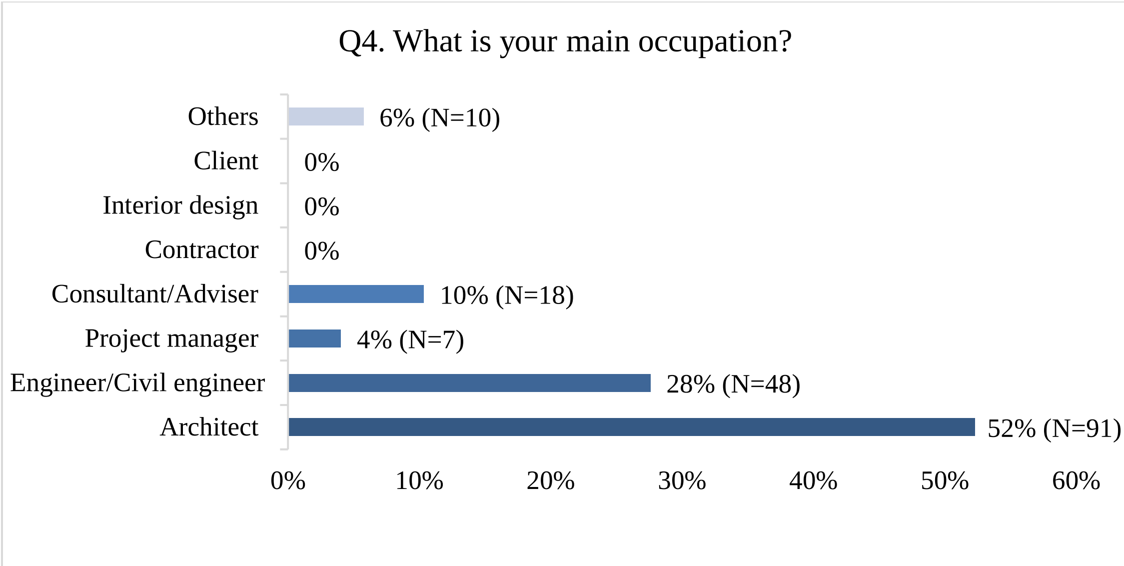

Figure 5.4: Current position of participants in Survey A

Occupation (Q4). **Figure 5.4** shows the distribution of employment among Survey A respondents. The largest group of respondents 52% (N=91) were architectural specialists, followed by engineers/civil engineers 28% (N=48), consultants/advisers 6% (N=10), and project managers 4% (N=7). There were no respondents from contractor, interior design, or client backgrounds in this survey.

These findings highlight the importance of considering the views and experiences of architectural specialists when exploring BIM adoption and implementation in architectural practice and education. Their perceptions can offer constructive perspectives on the challenges associated with BIM implementation in AECO practices.

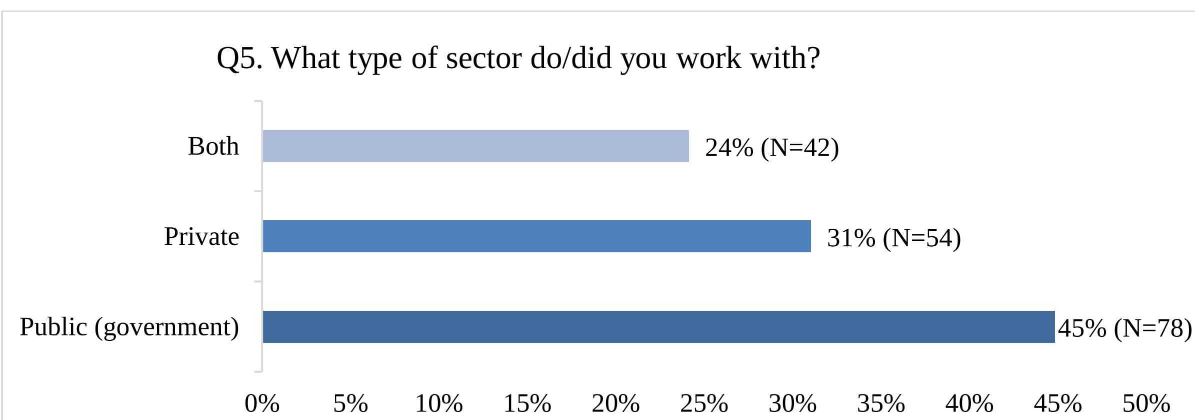

Figure 5.5: Sector types of participants in Survey A

Sector types (Q5). **Figure 5.5** shows the distribution of the employment sector among Survey A respondents. A substantial number of respondents, 45% (N=78) worked in the public sector, while 31% (N=54) of respondents indicated that they worked in the private sector, and 24% (N=42) of respondents reported working in both the public and private sector.

These findings highlight the diverse employment contexts within the Libyan AECO sectors, with significant participation from both the public and private sectors. Understanding the dynamics within these sectors is essential when considering adopting and implementing technologies like BIM, as it may involve engagement with various stakeholders and decision-makers from different backgrounds and organizational structures.

5.6.2 Part 2: Organisation Activities

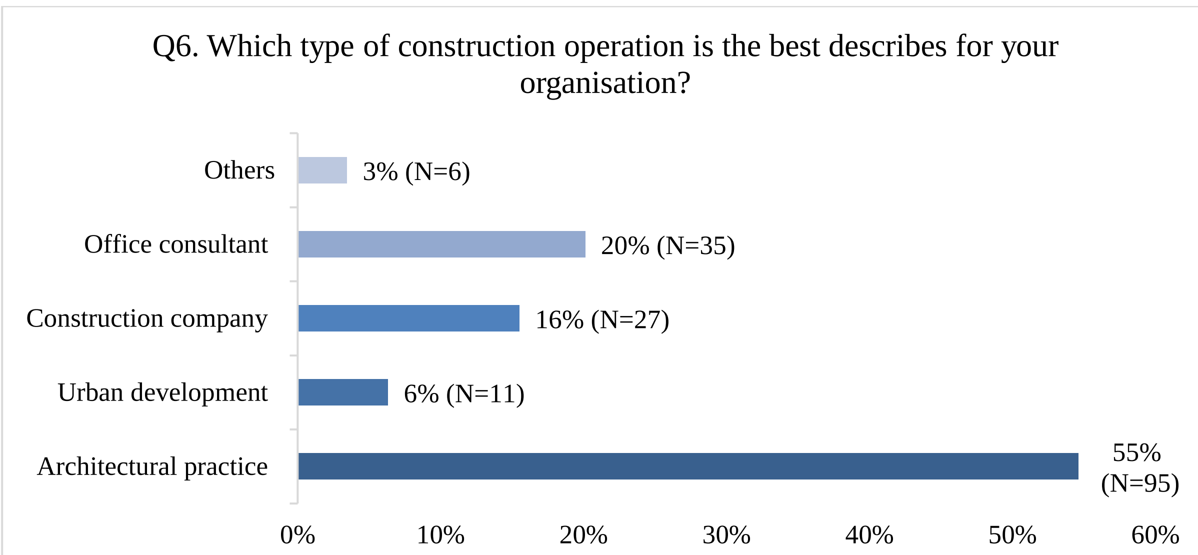

Figure 5.6: Type of construction operation projects in Survey A

Construction operation (Q6). **Figure 5.6** shows the types of construction operations in which the participants' organizations are engaged. The most common choice was architectural practice 55% (N=95), followed by office consultants 20% (N=35) and construction companies 16% (N=27). A smaller percentage of respondents 6% (N=11) indicated that their organizations are engaged in urban development activities.

These findings demonstrate the diversity of project types and areas of expertise within the Libyan AECO sectors. While architectural practice is the most prevalent, many professionals are involved in consulting, construction, and urban development. Understanding these roles is crucial for addressing the unique challenges and opportunities associated with BIM adoption and education within different AECO sectors.

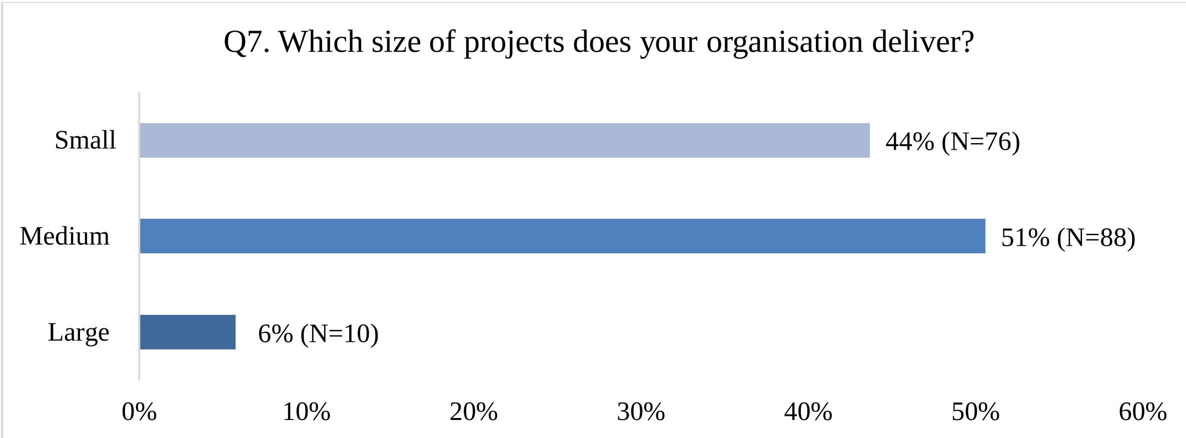

Figure 5.7: Project size of participants' organisation in Survey A

Project size (Q7). **Figure 5.7** shows the distribution of project sizes in the Libyan AECO sectors. Medium-sized projects are the most common with 51% (N=88) of respondents, and Small-sized projects were reported by a substantial number of respondents 44% (N=76), while only 6% (N=10) reported delivering large-sized projects.

These findings demonstrate that medium and small project sizes are the most prevalent, likely related to the country's current instability. Smaller and medium-sized projects may be more manageable and financially viable in such contexts. These findings highlight the importance of considering project size when discussing BIM adoption and implementation, as the applicability and benefits of BIM can vary depending on the scale and complexity of projects.

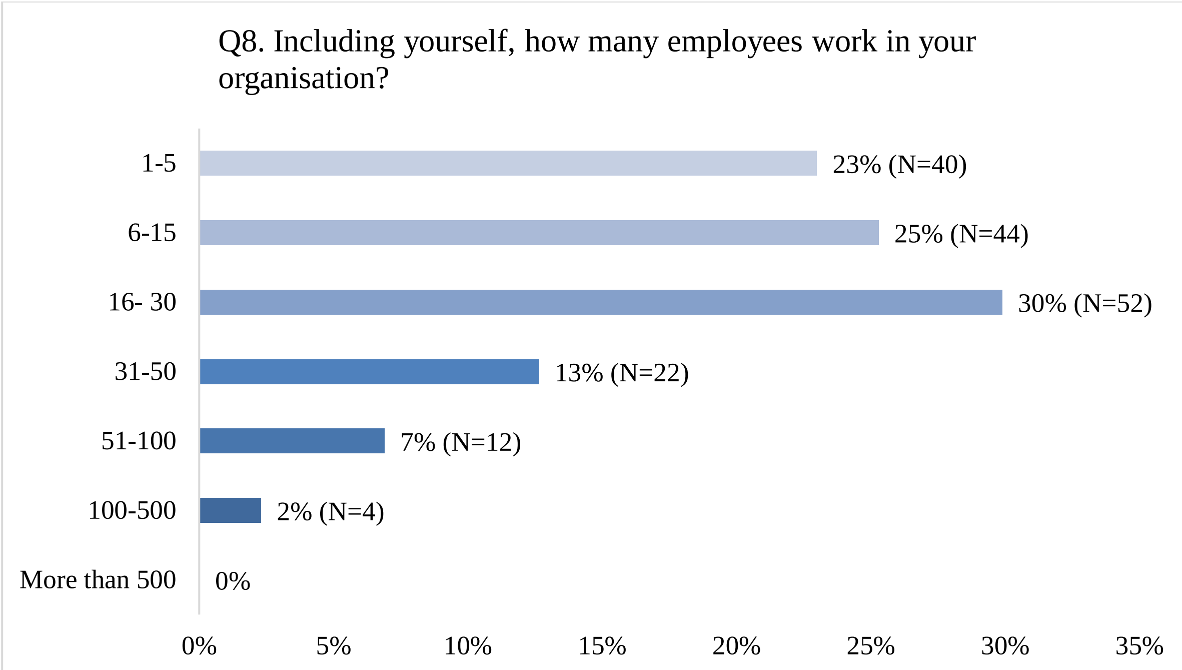

Figure 5.8: Number of organisation employees in Survey A

Employee Distribution (Q8). **Figure 5.8** shows the distribution of respondents based on the number of employees in their organizations. The majority of respondents (30%, N=52) represent organizations with no more than 30 employees, followed by organizations with 6 to 15 employees (25%, N=44) and organizations with 1 to 5 employees (23%, N=40). Larger companies with 30 to 51 and 51 to 100 employees constitute 13% (N=22) and 7% (N=12) of the sample, respectively. Firms with more than 100 to 500 employees reported the lowest response rate at only 2% (N=4).

This distribution highlights that the survey obtained significant engagement from small and medium-sized enterprises, while larger organisations were comparatively less represented. Potential factors contributing to this pattern may include organisational size, capacity, and economic considerations. It is crucial to acknowledge this dynamic when interpreting the survey findings, as smaller enterprises' perspectives, challenges, and requirements may differ substantially from those of their larger counterparts, particularly in adopting and implementing technologies like BIM.

5.6.3 Part 3: The Use of Digital Technologies

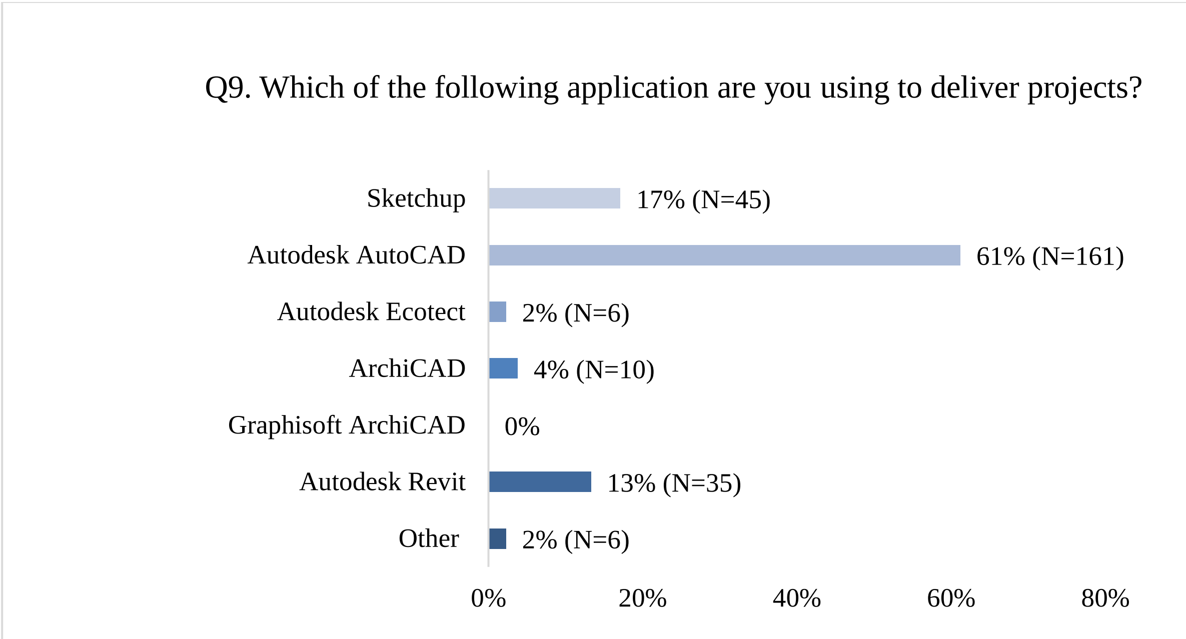

Figure 5.9: Fundamental software used to deliver projects by participants in Survey A.

Fundamental software used (Q9). **Figure 5.9** shows that AutoCAD emerged as the dominant choice, with a substantial majority of respondents (61%, N=161) indicating their use of AutoCAD. This preference for AutoCAD is consistent with a previous study conducted by Solla et al. in 2023, which found that AutoCAD was the most widely used CAD software in the Libyan AECO sectors.

SketchUp was the second-most used software, selected by 17% (N=45) of respondents. SketchUp's popularity is likely attributed to its user-friendly 3D modelling capabilities, which have grown in popularity in architectural design and visualization.

Revit, as the main BIM software, was chosen by 13% (N=35) of respondents. While this represents a smaller portion of respondents, it indicates a notable presence of BIM-related software within the surveyed population. The use of Revit suggests a recognition of BIM's importance and the adoption of BIM tools for project delivery.

The substantial gap between AutoCAD users and its closest competitor underscores AutoCAD's continued dominance as the market-leading 2D program, dominating the market. This historical and practical dependence on AutoCAD may be attributed to legacy factors, including file compatibility and familiarity. Additionally, the survey results indicate that most respondents (78%) have not fully embraced BIM or made it their primary platform for project deliverables. This observation aligns with the prevalent use of traditional 2D drafting software like AutoCAD, indicating potential room for further BIM adoption and integration within the sector.

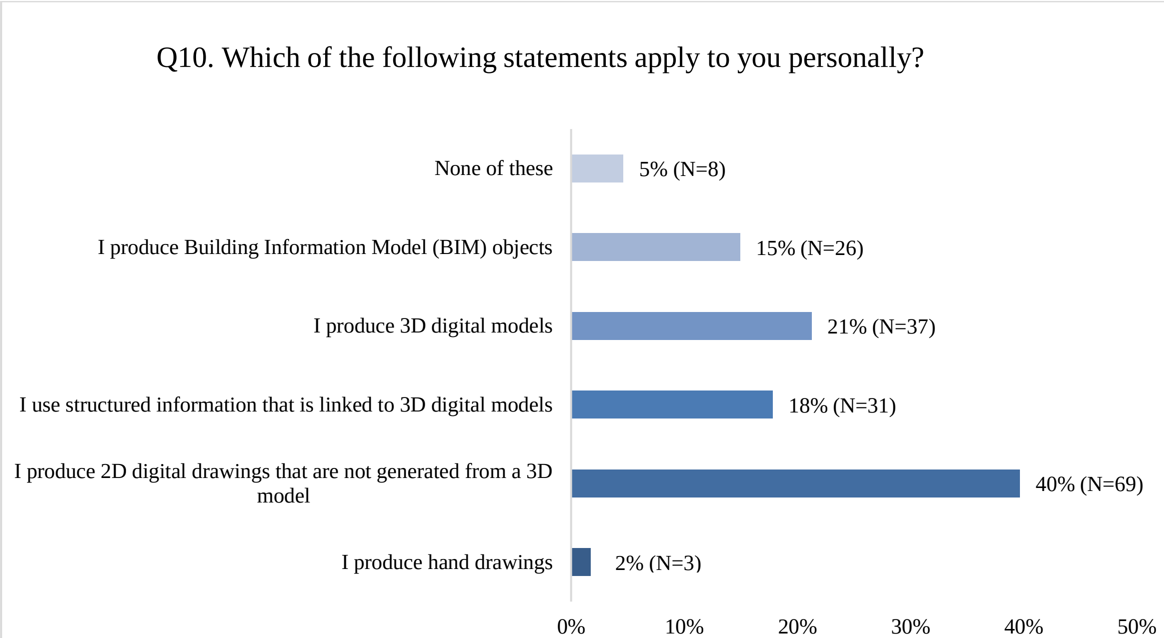

Figure 5.10: The project produces types by participants in Survey A

The project produces types (Q10). **Figure 5.10** shows the types of project deliverables produced by the participants. Most respondents, accounting for 40% (N=69) of the sample, reported that they created all or most of their projects in 2D drawings using CAD software. This finding is consistent with previous research of Elghdba et al. (2023) which emphasises the continued reliance on traditional 2D CAD tools for generating project deliverables and documentation in the sector.

In addition, a notable number of respondents 21% (N=37) indicated that they produced 3D digital models as part of their project deliverables. This suggests that many respondents have adopted 3D modelling as part of their project workflows, which aligns with AECO trends moving towards more visual design representations. Furthermore, 18% (N=31) of respondents reported using structured information linked to 3D digital models. This practice implies sophistication in project documentation, as it involves associating data with the 3D model elements, often a characteristic of BIM workflows.

However, only 15% (N=26) of respondents mentioned producing BIM models as part of their project deliverables. This shows that while there is some adoption of BIM, it is not yet a predominant practice within the surveyed population.

The survey results show that the Libyan AECO sectors demonstrate a mix of traditional and modern practices in project deliverables. While there is some utilization of 3D modelling and structured data, the majority of respondents still favour 2D CAD for project documentation. This finding is consistent with prior studies of Elghdba et al. (2023) and Solla et al. (2023) which indicate that the sector is gradually moving towards more advanced and integrated approaches.

5.6.4 Part 4: Awareness and Adoption of BIM

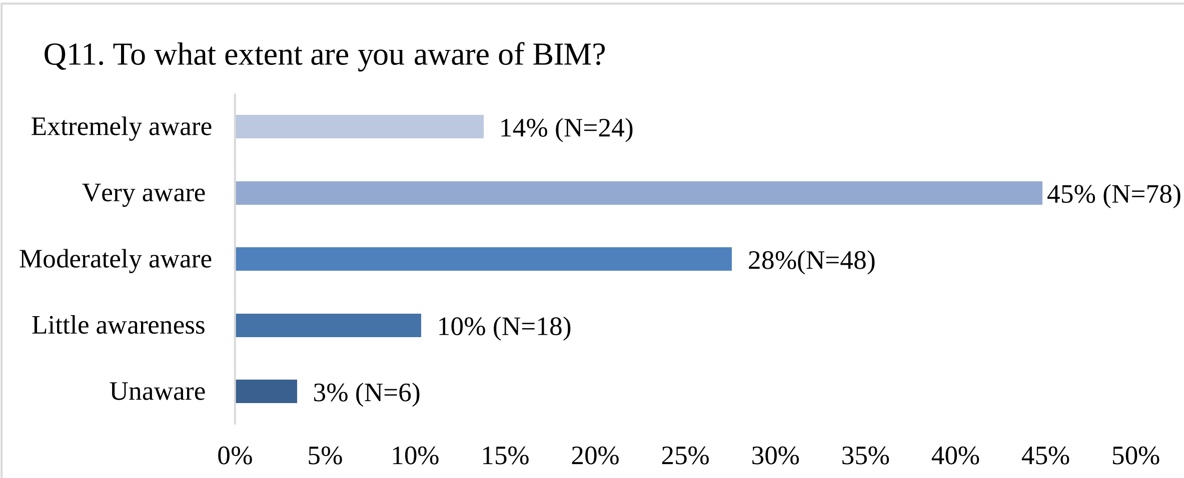

Figure 5.11: Level of BIM awareness between participants in Survey A

BIM awareness (Q11). **Figure 5.11** shows the level of BIM awareness among participants in the Libyan AECO sectors. A significant number of respondents, 45% (N=78), indicated that they were very aware of BIM, and 28% (N=48) of respondents stated that they were moderately aware of BIM. A smaller percentage of respondents, representing 14% (N=24), reported being extremely aware of BIM. While 10% (N=18) of respondents mentioned that they were little aware of BIM. Only 3% (N=6) of respondents stated they were unaware of BIM. These results show a reasonable level of awareness of BIM within the sector, but there is still an area for improvement.

The survey findings align with recent research on BIM adoption in Libya conducted by Saleh (2023), which identified a moderate level of awareness within the sector. This indicates a need for further education and training initiatives to enhance BIM adoption in the Libyan AECO sectors, as suggested by NATSPEC (2019). While there is a moderate level of awareness of BIM, there is an opportunity for expanding knowledge and awareness about BIM across the sector, which can contribute to more widespread adoption and obtaining the benefits of BIM in design and construction projects in Libya.

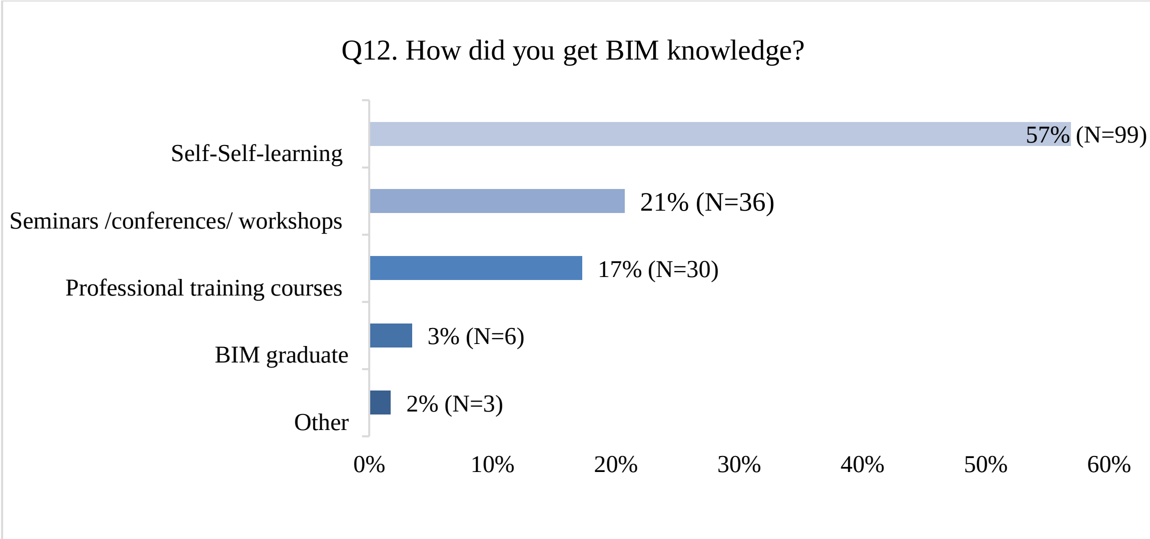

Figure 5.12: The method of BIM knowledge acquisition by participants in Survey A

BIM knowledge acquisition (Q12). **Figure 5.12** shows how respondents in the Libyan AECO sectors acquired their BIM knowledge and skills. A substantial majority of respondents 57% (N=99), indicated they received BIM knowledge through self-learning. In comparison, 21% (N=36) of respondents mentioned that they gained BIM knowledge through seminars and conferences. In contrast, 17% (N=30) of respondents reported that they acquired BIM knowledge through professional training courses. A smaller percentage, representing 3% (N=6) of participants, stated that they are BIM graduates. Only 2% (N=3) of respondents mentioned "other" options for acquiring BIM knowledge, suggesting a range of alternative methods that were not explicitly covered in the predefined categories.

The survey results found that self-learning is the primary method for acquiring BIM knowledge among professionals in the Libyan AECO sectors. This indicates that many professionals have taken the initiative to independently educate themselves about BIM, possibly through online resources, tutorials, or self-guided study. While self-learning demonstrates individual initiative and motivation, it may also indicate a gap in formal education and training opportunities related to BIM. The findings also highlight the need for comprehensive BIM education and training programmes to equip professionals with the necessary knowledge and practical skills to utilize BIM tools and processes effectively (Silverio et al., 2017). Embedding BIM education within architectural programmes can play a crucial role in producing qualified graduates capable of proficiently working with BIM in the AEC sector.

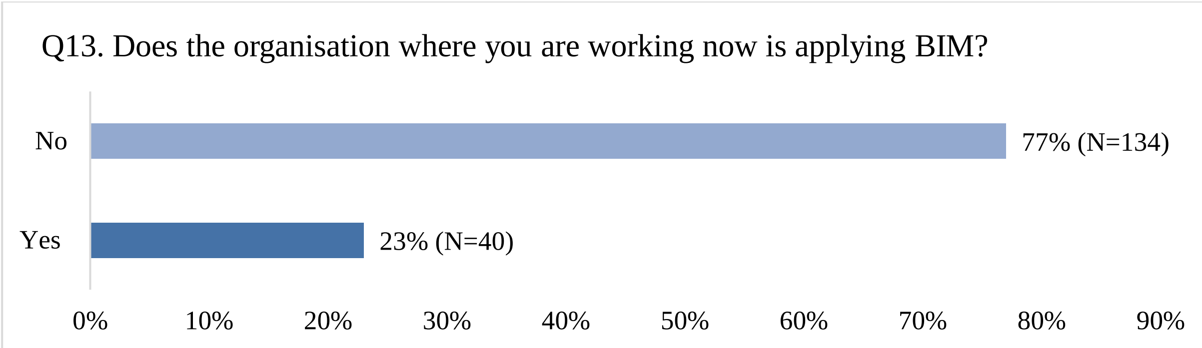

Figure 5.13: The organisation used BIM in Survey A

Organisations used BIM (Q13). **Figure 5.13** shows the level of BIM use, 77% (N=134) of participants reported that they had not used BIM in their organisations, while 23% (N=40) reported that they had used BIM.

The survey results found that BIM is still a low level of adoption among organizations in the Libyan AECO sectors. This finding is consistent with previous research findings of Elghdba et al. (2023) and Solla et al. (2023) which show the limited adoption of BIM within the Libyan AECO sectors. Several factors may contribute to the limited adoption of BIM in Libya, including economic conditions and the prevailing circumstances in the country. Additionally, organizations may face challenges and barriers, such as the availability of BIM-trained professionals, access to BIM software and resources, and the need for organizational change and investment.

Despite the low adoption rate, the presence of organizations that have adopted BIM indicates the potential for further development in BIM implementation within the Libyan AECO sectors. Addressing the barriers to adoption and promoting BIM awareness and education may facilitate the broader use of BIM in the future.

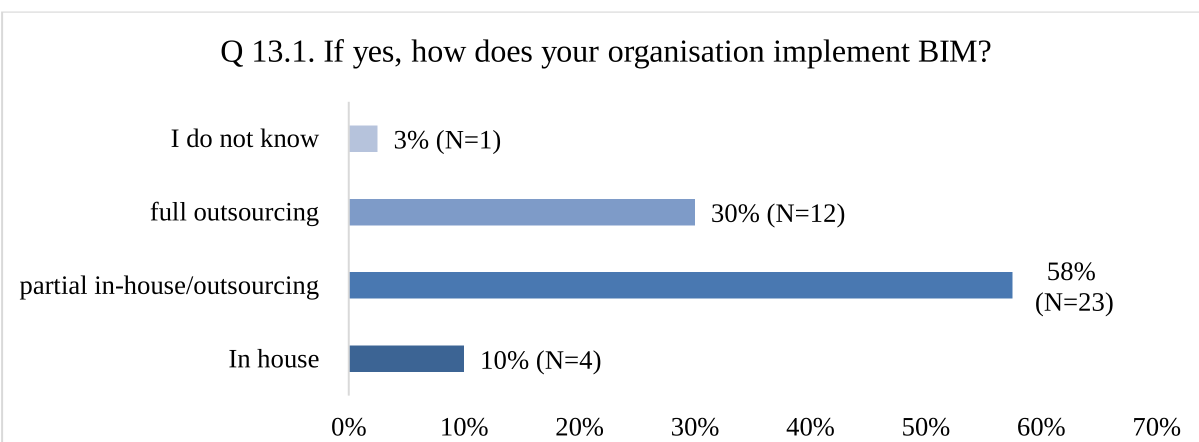

Figure 5.14: Organizations that implemented BIM in Survey A

Organisations that have implemented BIM (Q 13.1). This was a condition question for Q13 if respondents answered yes. This question got a total of 40 respondents who previously stated that their organisation had used BIM. This is an important question to understand how the organisation applies BIM. **Figure 5.14** shows that the majority of respondents 58% (N=23) reported that they implement BIM partially in-house and partially through outsourcing. In contrast, 30% (N=12) of respondents stated that their organizations fully outsource BIM implementation. In addition, 10% (N=4) of respondents mentioned that their organizations implement BIM by relying on the competency of their in-house staff. While a smaller percentage, representing 3% (N=1), answered that they do not know how their organizations implement BIM.

The survey results emphasise the variety of approaches organizations in Libya take when implementing BIM. The prevalence of outsourcing strategies reflects the need for specialized skills, especially in the early stages of BIM adoption. However, to ensure long-term sustainability, there is a growing emphasis on developing in-house competency and fostering a proficient BIM team (Casasayas et al., 2021). These findings contribute to a deeper understanding of BIM implementation strategies within the Libyan AECO sectors and are consistent with existing research in the field.

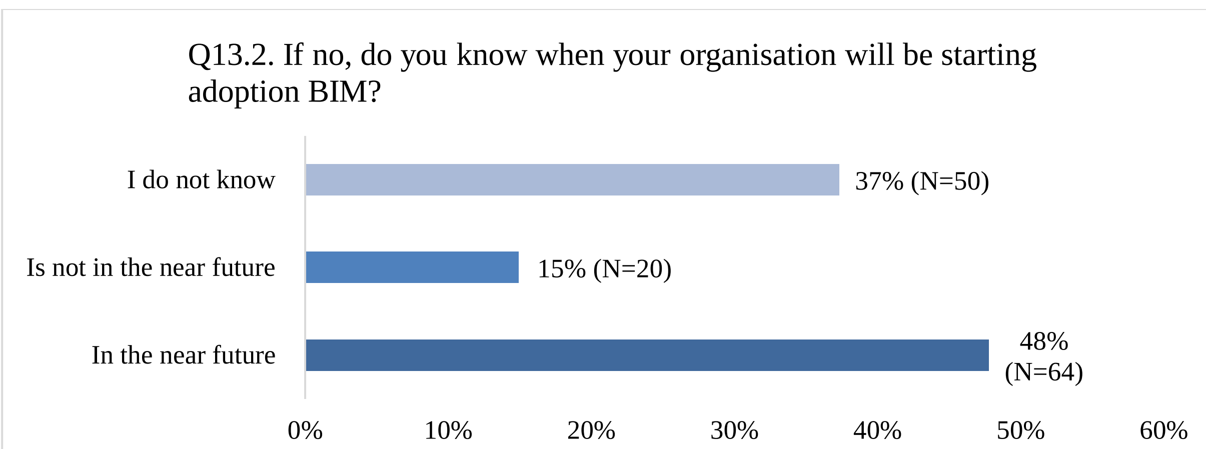

Figure 5.15: Organisations that have not used BIM in Survey A

Organisations that have not used BIM (Q13.1). This was a condition question for Q13 if respondents answered no. This question got a total of 134 respondents who previously stated that their organisations had not used BIM. It is critical to determine how many are genuinely considering taking the crucial step of embracing new technologies such as BIM. According to **Figure 5.15,** nearly 48% (N=64) indicated that they intend to adopt BIM technology in the near future. Approximately 37% (N=50) of respondents mentioned that they are unsure when their organizations can claim BIM adoption. Only 15% (N=20) of participants expressed that their organizations did not anticipate the adoption of BIM in the near future.

The survey results show a significant willingness among organizations in Libya to adopt BIM in the future. This is evidenced by the fact that nearly half of the respondents who have not yet used BIM intend to do so in the near future. The relatively low percentage of respondents who firmly opposed BIM adoption is also encouraging.

This willingness to adopt BIM emphasizes the importance of addressing the barriers and challenges that organizations may encounter in their BIM journey, such as resource constraints, training needs, and awareness gaps (Enshassi et al., 2018; NBS, 2019; Saka et al., 2020). Stakeholders, including educational institutions, industry associations, and government bodies, can play a pivotal role in providing the necessary support and guidance to encourage and facilitate organizations in their transition to BIM. By doing so, they contribute to the broader adoption of this technology within the Libyan AECO sectors, fostering innovation and improved project delivery.

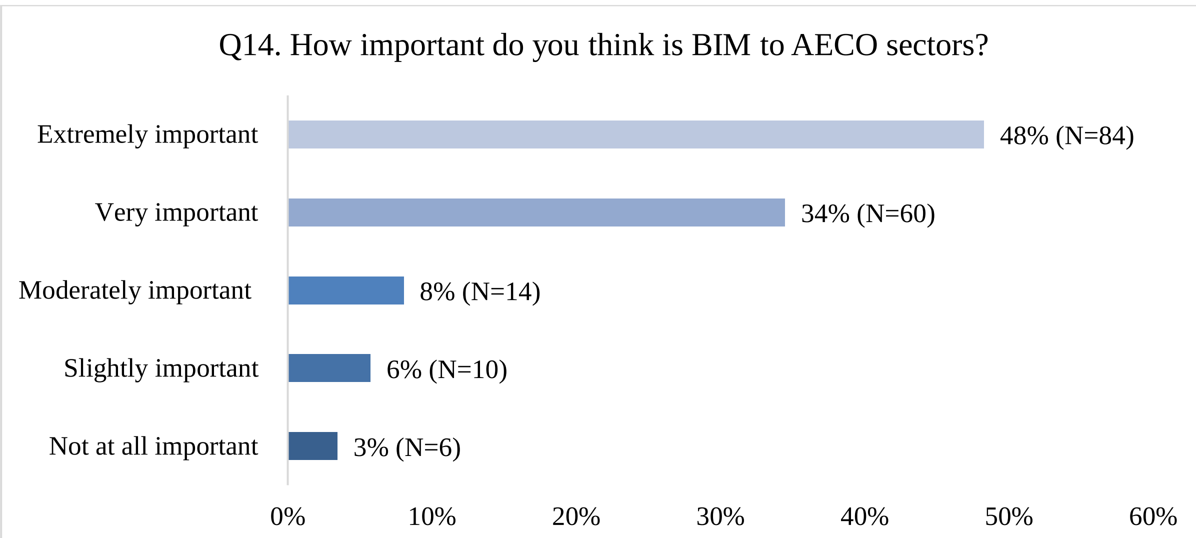

Figure 5.16: Importance of using BIM in the AECO sectors according to participants in Survey A

The importance of using BIM in the AECO sectors (Q14). **Figure 5.16** shows a substantial number of respondents, comprising 48% (N=84), expressed that they consider BIM extremely important to use in Libya's AECO sectors. Additionally, 34% (N=60) of respondents indicated that they believe it is very important for BIM to be adopted in the AECO sectors. While 8% (N=14) of respondents stated that they consider BIM moderately important, 6% (N=10) indicated that it is slightly important. Only 3% (N=6) of respondents expressed the opinion that BIM is not at all important for the AECO sectors in Libya.

The survey results illustrate a strong consensus among participants regarding the importance of BIM adoption within the Libyan AECO sectors. The substantial percentage of respondents deeming BIM as extremely and very important highlights the widespread recognition of BIM as a transformative technology and methodology. It is viewed as having the potential to enhance efficiency, collaboration, and overall project outcomes, aligning with global trends in the AECO sectors that emphasize the central role of BIM in modern construction and design practices (NBS Research, 2018; NFB, 2018; Moreno et al., 2019; NBS, 2019; RIBA, 2020).

5.6.5 Part 5: Training and Resources for BIM

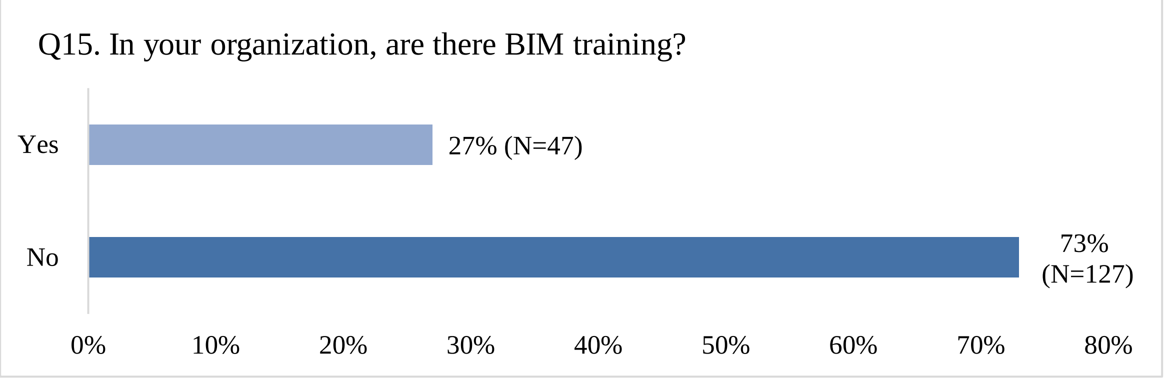

Figure 5.17: BIM training and learning in participants' organization in Survey A

BIM training and learning materials (Q15). **Figure 5.17** shows how Libyan organisations support BIM skills development among their staff. The majority of respondents, accounting for 73% (N=127), indicated that their organizations did not provide BIM training for their staff and did not have support materials for learning BIM. This reveals that many organizations within the surveyed population currently do not offer formal BIM training programs or learning resources for their employees.

Conversely, 27% (N=47) of respondents answered yes, indicating that their organizations provide in-house BIM training programs. These organizations have taken the initiative to develop and offer BIM training opportunities to their staff. This proactive approach may be driven by recognising the value of BIM skills and the need to equip employees with the necessary knowledge and competencies.

The survey results underscore a potential gap in BIM education and training within organizations in Libya. The significant majority of participants indicated that their organizations do not currently offer BIM training programs, potentially hindering the cultivation of a skilled workforce proficient in BIM technologies and methodologies.

Addressing this gap and promoting BIM education within architectural education is essential for advancing the broader adoption and effective utilisation of BIM in the Libyan AECO sectors (Saleh, 2015; Adamu and Thorpe, 2016). Encouraging organisations to invest in BIM training and provide learning materials can facilitate the development of a competent workforce ready to embrace BIM technology, enhancing project delivery and competitiveness within the industry. This aligns with the global trend of industry stakeholders recognizing the significance of investing in BIM education and training to drive innovation and excellence (Borrmann et al., 2018; Eastman, 2018; NBS, 2019).

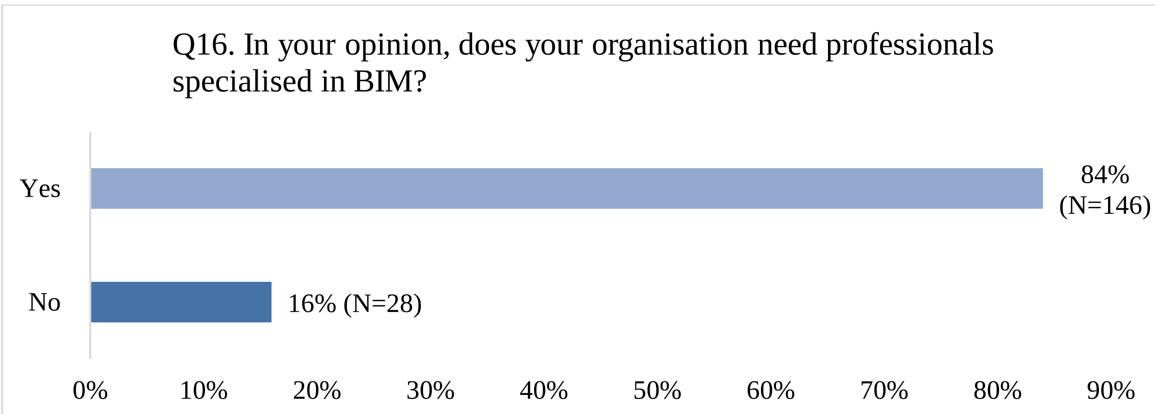

Figure 5.18: Assistance needs to lead BIM adoption according to participants in Survey A

Assistance needs to lead BIM adoption within organizations (Q16). **Figure 5.18** shows that the majority of respondents, comprising 84% (N=146), stated that their organizations would need professionals specialized in BIM to lead the BIM adoption process. Conversely, only 16% (N=28) of respondents indicated that their organizations would not require BIM specialists to lead BIM adoption.

The survey results emphasize the critical role that BIM specialists can play in facilitating the successful adoption and integration of BIM within organizations. BIM specialists can offer valuable expertise, training, and strategic direction to ensure that BIM is effectively leveraged to improve workflows, collaboration, and project outcomes in the AECO sectors (Kiviniemi, 2017). The strong endorsement of the need for BIM specialists highlights the recognition of their importance in navigating the complexities of BIM adoption.

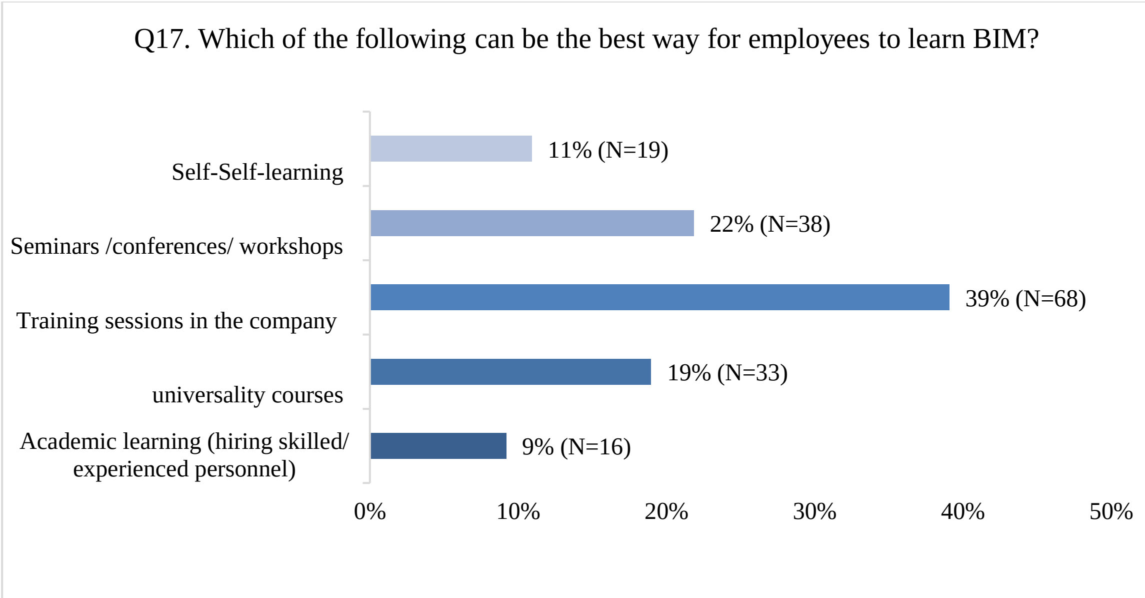

Figure 5.19: BIM learning methods for employees, according to participants in Survey A

BIM learning methods (Q17). **Figure 5.19** shows how organizations in Libya view the ideal approaches to BIM education and skill development. Among the options provided, the most preferred method for learning BIM, chosen by almost 39% (N=68) of respondents, is to have in-house training sessions within the company. Workshops and seminars were the second most preferred method, with 22% (N=38) of respondents selecting this option. 19% (N=33) of respondents preferred BIM courses at universities, highlighting the recognition of formal academic programmes as a valuable source of BIM education. 11% (N=19) of respondents indicated a preference for self-learning, and only 9% (N=16) of respondents favoured hiring experienced BIM personnel with a BIM education background.

The survey results reveal diverse preferences for BIM learning methods, with in-house training sessions and workshops/seminars being the top choices. However, it is also essential for universities to work alongside industry requirements (Adamu and Thorpe, 2016) and offer BIM courses, particularly for those companies having insufficient funding to deliver training (Kiviniemi, 2017).

5.6.6 Part 6: Barriers and key drivers of BIM adoption

Table 5.1: BIM adoption challenges for participants in Survey A

Challenges	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
Lack of awareness	53% 92	32% 55	5% 9	5% 9	5% 9
Lack of resources	42% 73	37% 65	16% 27	5% 9	0% 0
Lack of training	63% 110	32% 55	5% 9	0% 0	0% 0
Lack of demanded	42% 73	21% 36	16% 27	11% 19	11% 19
High investment; (software, hardware, & training)	37% 64	16% 27	32% 55	11% 19	5% 9
lack of a skilled workforce	47% 82	32% 55	16% 28	5% 9	0% 0
lack of government support	47% 82	16% 28	21% 36	11% 19	5% 9
Lack of collaborative process	26% 46	32% 55	21% 37	16% 27	5% 9
lack of standardised approach	36% 62	32% 55	14% 24	14% 24	5% 9
Resistance of change	26% 46	52% 91	16% 27	6% 10	0% 0

BIM adoption challenges (Q18). As with any novel technology or methodology, some obstacles should be anticipated. However, it was critical to obtain feedback from professional respondents to help identify the most significant barriers and thus guide the course toward a sustainable BIM adoption strategy. **Table 5.1** illustrate the ten identified challenges from the literature, and the responses shed light on the extent to which respondents recognise these challenges. The most significant challenges to BIM adoption, as strongly agreed upon by respondents, are as follows:

- Lack of appropriate training: A substantial majority of respondents, accounting for 63% (N=110), strongly agree that proper training is a significant barrier to BIM adoption. This aligns with the findings from Saka et al., (2020), which underscores the importance of addressing the skills gap and providing comprehensive BIM training.
- Lack of awareness: 53% (N=92) of respondents strongly agree that a lack of awareness about BIM is a significant challenge. This finding is consistent with the results of a recent survey by Solla et al. (2023), which emphasises the need for

awareness campaigns and educational initiatives to inform industry stakeholders about the benefits of BIM.

- Lack of government support: 47% (N=82) of respondents strongly agree that the lack of government support is a significant barrier to BIM adoption. Government backing and policy frameworks can play a crucial role in promoting BIM within the industry (Babatunde et al., 2021), and addressing this challenge may require advocacy for supportive policies.
- Lack of skilled workforce: A substantial portion of respondents, comprising 47% (N=82), strongly agree that the lack of a skilled workforce is a significant challenge. Building a competent BIM-ready workforce is essential to drive successful adoption.
- Resistance to change: 52% (N=91) of respondents somewhat agree that resistance to change is a significant challenge in the context of BIM adoption. This observation corresponds with the perspective provided by Borrmann et al. (2018), suggesting that cultural change management efforts may be required to overcome resistance to new technologies and processes.

The survey results are consistent with the broader body of research on BIM adoption challenges in AECO sectors, as reflected in the studies of the BIM in Africa by Saka et al., (2020) Solla et al. (2023), and Babatunde et al. (2021). The challenges identified in training, awareness, government support, workforce development, and resistance to change are well-documented in the literature and reinforce the need for a strategic and collaborative approach to overcome these barriers and foster widespread BIM adoption in the AECO sectors in Libya.

Table 5.2: Key drivers of BIM adoption

Key driver factors of BIM implementation	**Strongly agree**	**Somewhat agree**	**Neither agree nor disagree**	**Somewhat disagree**	**Strongly disagree**
Government mandate and support of BIM	68% 119	16% 28	5% 9	5% 9	5% 9
Availability of a standardised approach	21% 36	53% 92	16% 27	11% 19	0% 0
Availability of BIM resources	26% 45	32% 56	26% 45	11% 19	5% 9
Providing appropriate training	74% 129	21% 36	5% 9	0% 0	0% 0
Availability of adequate research	37% 64	26% 46	21% 36	11% 19	5% 9
Universities leading BIM adoption and promotion	21% 37	63% 109	11% 19	5% 9	0% 0

Factors drivers BIM adoption (Q19). **Table 5.2** illustrates the responses and highlights the following key drivers:

- Appropriate staff training: The most significant driver, with 74% (N=129) of respondents strongly agreeing, is providing proper staff training. This underlines the critical importance of investing in comprehensive BIM education and training programs to equip professionals with the necessary skills and knowledge to use BIM tools effectively. Ahmed (2018) stated that effective adoption of BIM demands a high level of education and training.
- Government mandate and support: 68% (N=119) of respondents strongly agree that government mandates and support for BIM adoption are imperative. This validates the perspective of Babatunde et al. (2021), who pointed out that government policies and regulations can play a pivotal role in driving BIM adoption within the sector.
- Universities leading adoption: 63% (N=109) of respondents somewhat agree that universities should adopt and promote BIM by providing graduates with BIM knowledge and skills. This highlights the role of academic institutions in shaping the future workforce and promoting BIM as an integral part of education.
- Standardized approach: 53% (N=92) of respondents somewhat agree on the importance of a standardized approach that facilitates BIM adoption as a new approach in firms. This supports the view that standardization can streamline processes, improve interoperability, and create consistency in BIM implementation across the industry (Borrmann et al., 2018; Solla et al., 2023).

These key drivers underscore the importance of a holistic approach to BIM adoption, including education and training, government support, collaboration with universities, and the establishment of standardized practices. This approach is in line with the insights of Amer and Binhanafi (2016) and Kouch et al. (2018). By addressing these drivers, stakeholders in the AECO sectors in Libya can work toward a more prosperous and widespread adoption of BIM, which, as suggested by prior research, can lead to improved project outcomes and increased efficiency in construction and design processes.

5.6.7 Part 7: Professionals' Expectations Regarding BIM Education

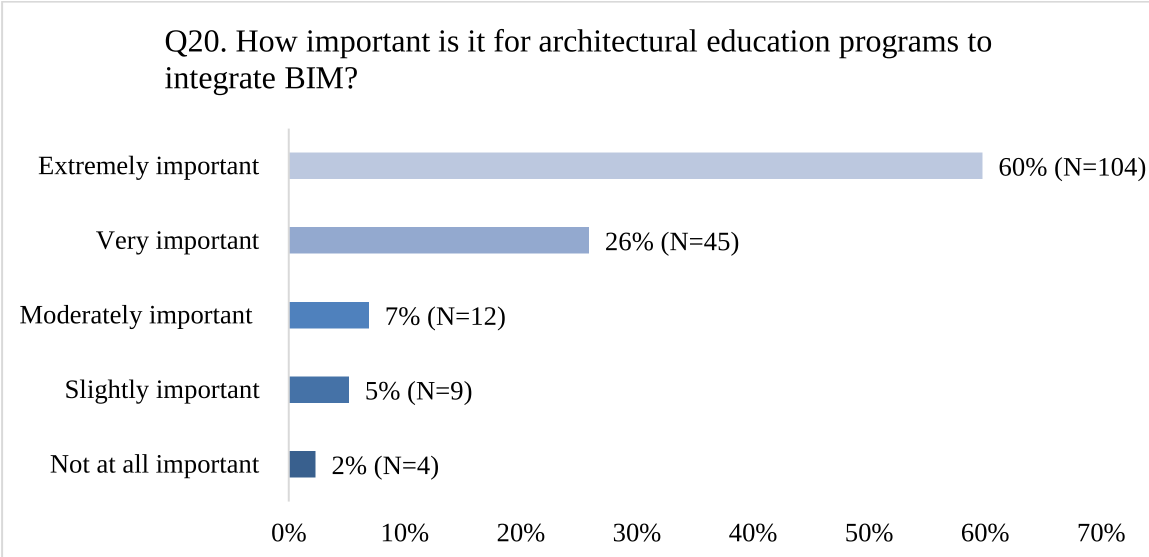

Figure 5.20: The importance of BIM education according to participants in Survey A

The importance of BIM education for architectural education (Q20). **Figure 5.20** shows that most respondents 60% (N=104), believe BIM education is extremely important. Additionally, 26% (N=45) of respondents consider BIM education to be very important for architectural education. These findings highlight a clear consensus among the survey participants regarding the significance of incorporating BIM into architectural curricula.

A minority of respondents, 7% (N=12), find it to be moderately important, only 5% (N=9) of respondents see BIM education as slightly important, and a mere 2% (N=4) believe that integrating BIM education into architectural education programs is not at all important.

The findings of this study, in agreement with previous research conducted by Alizadehsalehi et al. (2021), Labib and Nagy (2020), Elias, Issa, and Wu (2022), and Aljad (2023), highlight the consensus among respondents regarding the importance of integrating BIM education into architectural education programs. This confirmation underlines the need for BIM education integration in architectural education to equip future architects with the skills and knowledge required to meet the evolving demands of the AECO sectors. The alignment between the survey results and prior research supports the argument for the integration of BIM education into architectural curricula, which benefits both students and the architectural profession.

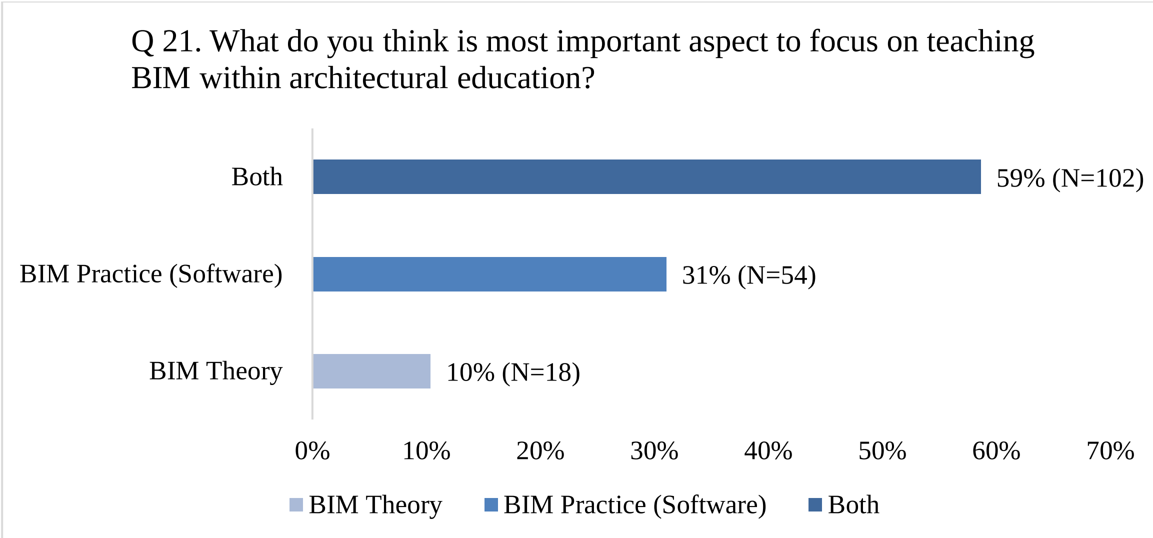

Figure 5.21: BIM education aspects in architectural education according to participants in Survey A

BIM training aspects (Q21). **Figure 5.21** shows AECO professionals' expectations regarding the skills and knowledge of recent graduates. The majority of respondents, comprising 59% (N=102), indicated that they are looking for new graduates with a combination of BIM practical skills and theory. While 31% (N=54) of respondents emphasized the importance of BIM practical skills in new graduates, only 10% (N=18) selected BIM theory as the desired ability for new graduates.

The findings of this survey align with the findings provided by previous research conducted by Puolitaival and Forsythe (2016), Boton et al. (2018), and Chen et al. (2020). These studies underline the importance of comprehensive BIM education programmes that offer students a solid foundation in BIM theory while also equipping them with the practical skills required to effectively utilize BIM tools and processes in real-world projects. Furthermore, the survey results highlight that the AECO sectors's expectations are consistent with the need for a holistic BIM educational approach. The approach should aim to prepare graduates in order to bridge the gap between theory and practice in architecture, engineering, and construction.

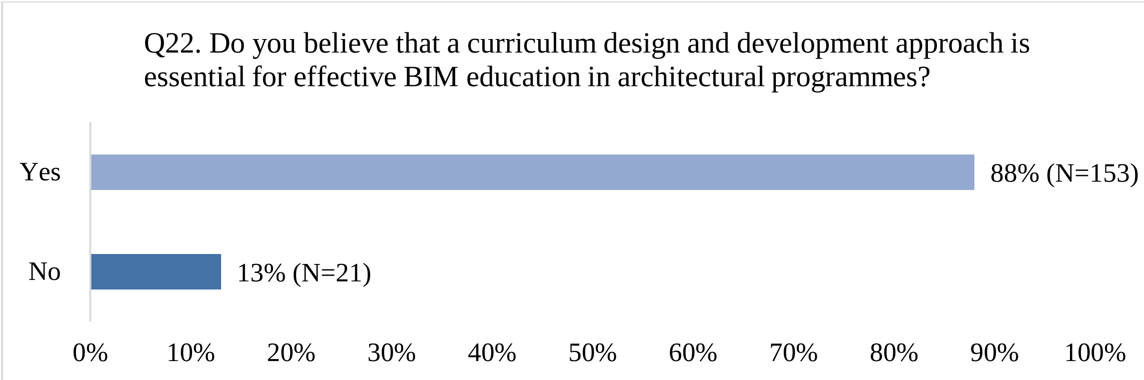

Figure 5.22: The need for BIM curriculum according to participants in Survey A.

The need for BIM curriculum design and development (Q22). **Figure 5.22** shows that a significant majority, 88% (N=153) of respondents strongly believe that a curriculum design and development approach is essential for effective BIM education. On the other hand, 13% (N=21) of respondents do not believe that a curriculum design and development approach is essential.

This finding aligns with the broader trend of recognising the need for systematic and organized approaches to integrate BIM into educational programs for future architects. This perspective is consistent with the findings provided by prior research conducted by Abdirad and Dossick (2016) and Coates et al. (2018), who emphasise the importance of structured curriculum design and development in ensuring that BIM concepts and tools are effectively taught within architectural education. The survey results confirm the ongoing recognition of this need within the field, emphasising the argument for a well-organised BIM curriculum in architectural education.

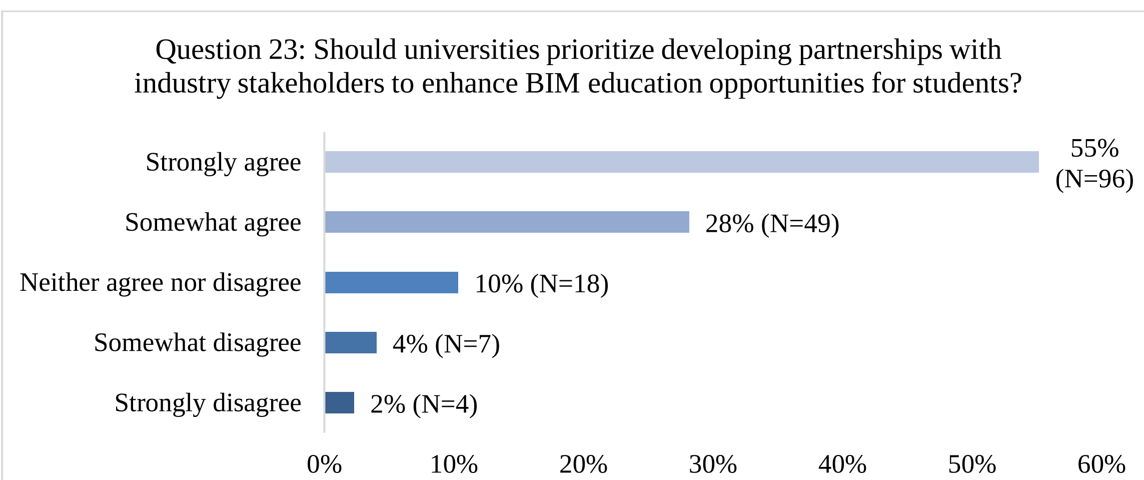

Figure 5.23: The importance of academic and professional partnerships, according to participants in Survey A.

The importance of academic and professional partnerships (Q23). **Figure 5.23** shows that a substantial majority, 55% (N=96), strongly agree that universities should prioritize these partnerships. Additionally, 28% (N=49) of respondents agree that universities should prioritize developing partnerships with industry stakeholders to enhance BIM education opportunities for students. A smaller portion of respondents, 10% (N=18), have a neutral stance, neither strongly agreeing nor disagreeing. Only 6% (N=11) of respondents either disagree or strongly disagree with the prioritization of partnerships with industry stakeholders.

These findings align with the growing recognition of the importance of industry-academic partnerships in the field of BIM education. This perspective is consistent with insights provided by previous research conducted by Silverio et al. (2016), Casasayas et al. (2021), and Abdelhai (2022), which emphasize the important role of such collaborations in providing students with real-world experiences and keeping educational programmes in line with AECO requirements.

5.7 Findings from Survey A

Based on the respondents' perspectives, the summary of findings from Survey A provides valuable insights into the experiences, awareness, utilization of BIM, and organizational practices related to BIM adoption and training among professionals in the AECO sectors in Libya. Here are the key findings.

- AutoCAD is the current dominant software used in the Libyan architectural practice to deliver projects. This indicates that most respondents created all or most of their 2D drawings using CAD software.
- There is a lack of BIM awareness among Libyan professionals who are currently moderately aware. Therefore, there is a need for more workshops and professional and academic courses to increase BIM awareness among professionals.
- Regarding BIM skill acquisition, most of the participants acquired BIM skills through self-learning. This means that most participants lack adequate BIM training, leaving them without sufficient practical skills to produce a complete BIM model. The incentives will encourage professionals to sharpen their skills through enrolling in training programs and attending seminars and workshops rather than self-sponsoring.
- BIM adoption is still in the initial use stage in the Libya AECO sectors. This is due to a lack of BIM-competent workforce in companies. The implementation of BIM relies on outsourcing staff competency, which does not support long-term demands.

- Among non-BIM users, organizations intend to adopt BIM technology in the near future. The results indicate that participants are willing to adopt BIM in their organisations, which shows that the current situation may change in the future and that they may adopt BIM technology.
- On the importance of BIM use in the AECO sectors, most respondents agreed that BIM is extremely important to implement in the AECO sectors in Libya.
- As per the respondents, the major challenge facing BIM adoption in Libya is the lack of appropriate training, lack of awareness, lack of government support, and lack of skilled workforce are the significant challenges to BIM adoption in Libya AECO sectors.
- Respondents believe that providing the appropriate staff training, BIM mandate by the government, and proper support are the primary key drivers for BIM adoption in the AECO sectors in Libya.
- There is a lack of BIM training and learning materials in organizations. As indicated by most participants, their organisations do not provide BIM training programs for their staff, which can load more costs for organizations and staff to have BIM training courses.
- In terms of assistance needed to implement BIM, most respondents stated that their organization needed assistance to implement BIM. This is due to the lack of BIM specialists in the organisation to lead BIM adoption.
- Importance of BIM education for architectural education: Respondents considered integrating BIM into architectural education programs extremely important, highlighting the need to adapt BIM education based on sector demands.
- Expectations for graduates: Respondents expect new graduates to have a combination of BIM practical skills and theory, emphasizing the importance of a balanced skill set.
- BIM curriculum design and development: The majority (88%) believe that curriculum design and development are essential for effective BIM education.
- Academic and professional partnerships: Most respondents agree that universities should prioritize partnerships with industry stakeholders to enhance BIM education opportunities for students.

5.8 Summary

This chapter analyses quantitative data from a questionnaire-based survey (Survey A) conducted with practitioners in Libya's AECO sectors. Survey A reveals valuable insights into the current state of BIM adoption and training in Libya. Although AutoCAD is still dominant, there's a growing interest in BIM. However, key challenges hinder progress includes limited BIM awareness and skills, inadequate training and resources, and a shortage of BIM-competent professionals. Despite these challenges, the outlook is positive. Most respondents recognize the importance of BIM and express a willingness to adopt it. The survey identifies key drivers for BIM adoption; providing BIM training programmes, government support, and integrating BIM into architectural education would prepare future professionals with essential BIM expertise.

The survey underscores the critical need for collaboration between academic institutions and industry stakeholders. By addressing the identified challenges and implementing the suggested drivers, the Libyan AECO sectors can successfully embrace BIM and unlock its potential for improved project delivery and collaboration.

Chapter 6: BIM-Oriented Architectural Education in Libya

This chapter aims to present the findings from questionnaire-based Survey B (See a copy of the questionnaire in **Annex 4**), which was conducted with Libyan educators to determine BIM awareness, teaching strategies, integration, and university educators' academic readiness for integrating BIM into architectural programs and their capacity to produce competent graduates for the growing demand for BIM skills in the AECO sectors. The chapter offers reviews and discussions, including (1) an overview of Survey B, (2) sampling approach, (3) questionnaire design, (4) considerations, (5) data analysis process, and (6) summary.

6.1 Questionnaire-Based Survey B

Survey B was created and distributed to academics in Libyan higher education, practically architectural schools. The survey elicited Libyan academics' attitudes toward BIM education and best practices for adopting it in architectural education. This questionnaire aims to identify (1) the use of digital technology, (2) BIM Awareness, importance, and responsibility for delivering BIM into universities, (3) identify current and preferred teaching and learning strategies for BIM education, (4) discover the universities readiness and challenges for BIM education and identify the resources needed to support BIM learning.

Survey B was distributed using different methods. These methods are email invitations, social networks (Facebook and LinkedIn), and manual entry. The questionnaire was conducted from 10th April to 15th July 2021, a duration of three months. A total of 227 respondents had completed the survey with the following breakdown by distribution method.

- Manual entry: 158 respondents, primarily gathered by the researcher's visits to local architectural schools to collect data.
- Social Networks: 45 respondents, distributed through communication apps like ResearchGate, LinkedIn, Facebook, and WhatsApp by sharing the questionnaire link.
- Email invitation: 22 respondents, sending emails to 35 Libyan educators in architectural education with research information.

6.2 Sampling Approach

As discussed in **Section 4.4.2**, on Sampling Techniques for Survey B, surveying the entire population of Libyan architectural schools is often impractical, and time-consuming. Therefore, the study used a targeted survey focused on Libya's state-run architectural schools due to feasibility, accessibility, and their major role in shaping the field. This approach aims to accurately represent public architectural education in Libya despite not reaching all schools.

6.3 The Design of Survey B

Survey B is a structured questionnaire designed to gain an understanding of Libyan architectural educators' experiences with BIM integration in their undergraduate architectural programmes. The survey employs a mixed-methods approach, combining closed-ended and open-ended questions to gather data on BIM education status in undergraduate architectural programmes in Libya. The survey's structure and content are grounded in two well-known frameworks:

- TPACK Framework: This framework helps to understand how educators combine knowledge of BIM technology (Technological Knowledge), effective teaching approaches (Pedagogical Knowledge), and architectural content (Content Knowledge) to integrate BIM effectively.
- CDIO Approach: This framework aligns with the hands-on nature of BIM and architectural education. By assessing educators' familiarity with the CDIO approach, it helps to gain insights into their readiness to incorporate practical BIM tasks into the curriculum.

The survey consists of 23 questions, strategically organized into five key parts to explore various facets of BIM integration in architectural education:

- Part 1: General Information. This part collects basic demographic information about respondents, including age, teaching experience, qualifications, position, university affiliation, and department. This helps to contextualize the responders' responses within the framework of their professional experience.
- Part 2: Digital Technology Use. This part investigates the use of digital technologies in existing architectural programmes, focusing on the tools taught and their primary purposes which aligns with the CDIO's emphasis on using appropriate technologies for conceiving and designing architectural projects. This allows to assess the current state of technology usage (Technological Knowledge) in teaching and how it relates to content delivery and pedagogy.

- Part 3: BIM Awareness, Importance, and Integration Responsibilities. This part explores educators' awareness and perception of BIM in architectural education and explore into their views on BIM's importance and who they believe should be responsible for its integration. This helps to understand educators' TPACK (Technological Pedagogical Knowledge) regarding BIM and identify potential stakeholders for successful implementation.
- Part 4: Teaching and Learning Strategies for BIM Education. This part investigates educators' strategies and challenges when integrating BIM into their curriculum. It helps to explore educators’ perspectives on necessary changes, aligning with the CDIO's focus on designing and implementing practical learning experiences relevant to real-world practices (TPACK - Pedagogical Knowledge and CDIO - Implementation Knowledge). This analysis reveals how educators leverage technology with teaching methods to enhance student learning with BIM.
- Part 5: University Readiness and Challenges for BIM Education. This part assesses universities' preparedness to integrate BIM into their curricula. It also identifies potential challenges that might hinder successful implementation (TPACK - Contextual Knowledge and CDIO - Operation Knowledge). This helps to understand the level of institutional support for BIM and its impact on teaching and learning outcomes.

6.4 Considerations

The candidate employed a rigorous design process to minimize bias and optimize the survey for architectural educators. The structure was carefully designed to be concise and user-friendly, promoting high participation rates. To ensure its effectiveness, the survey underwent a series of pilot studies involving 13 participants, including 6 PhD students from the University of Strathclyde and 7 Libyan architectural educators. These participants offered feedback on question clarity, potential biases, and overall survey structure, providing valuable insights into its real-world application within the target field of architectural education.

Based on the pilot studies, the candidate refined the survey in several ways. The order and types of questions, including both closed and open-ended questions, were optimized for improved flow and clarity. The visual presentation was enhanced to create a more user-friendly experience. Clear and concise language, made to the target audience, was used throughout. Questions were reframed to eliminate ambiguity and potential biases. Additionally, the response choices were adjusted to ensure they adequately captured the range of potential viewpoints. These refinements significantly improved the survey's effectiveness, making it more accessible and reliable for participants, ultimately leading to more accurate and valuable data collection.

6.5 Data Analysis for Survey B

The data analysis phase in the context of Survey B is an indispensable element within the research endeavour. Three discrete stages delineate it: (1) data preparation, (2) descriptive statistics, and (3) coding of open-ended questions. These stages play a fundamental role in the process of extracting substantively meaningful insights and facilitating the formulation of empirically sound conclusions. These stages must be meticulously executed to uphold the research's integrity, ensuring the veracity and credibility of the findings generated therein.

6.5.1 Data Preparation

This stage is used to organize the data in preparation for analysis. As a result, the candidate prepared the data by checking, logging, and tracing questionnaire responses. The candidate created a structured classified database with Microsoft Access to record incoming data, allowing access to the recorded data and outstanding data results at any time. This also preserved the original data records for a reasonable time, allowing for the cost-effective tracking of data analysis results back to the original documents from which the data was collected.

6.5.2 Descriptive Statistics

This stage describes and explains the collected data's fundamental characteristics. The candidate sought to provide essential descriptive summaries for each sample to deconstruct the data and facilitate the process of developing visuals, analysis, and calculation to describe the data understandably and draw conclusions about a given data set. The candidate included descriptive elaboration, graphic analysis, and calculations for each question and sub-question to make the data more understandable after ensuring that all data was distributed in the most appropriate format and with the most appropriate description. The candidate used statistical analysis using frequency distribution analysis to describe the data, as the questionnaire surveys were designed to elicit a large number of responses.

6.5.3 Coding of Open-Ended Questions

The responses to all open-ended questions were coded to create a separate theme. The candidate created a coding structure or checklist that categorizes the responses received concerning the researcher's questions and their related codes. The coding method chosen was descriptive coding, which entails creating summary summaries of all the response texts to open-ended questions to maintain the survey's objectivity.

6.6 Results from Survey B

This section provides an analysis and discussion of data and results from Survey B that have been collected. Data were statistically analysed using frequency distribution analysis, and survey results are presented and discussed in five parts in this section.

6.6.1 Part 1: General Information

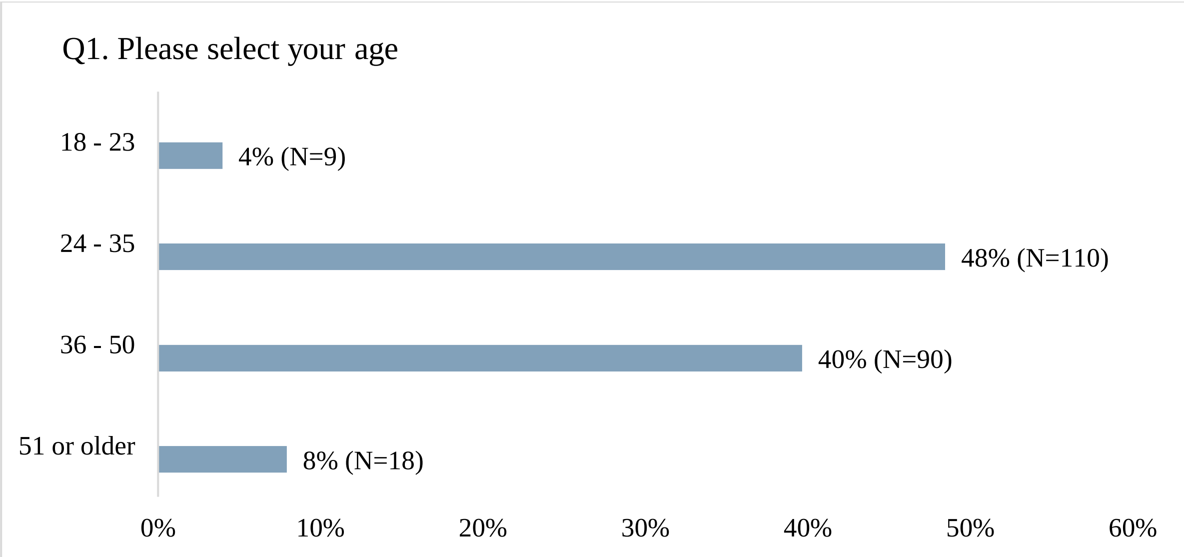

Figure 6.1: Age distribution of participants in Survey B.

Age (Q1). Respondents were asked to indicate their age group in question one, as shown in **Figure 6.1**, which reveals that the majority of respondents, comprising 48% (N=110), are aged 24-35, followed by 40% (N=90) aged 36-50. A smaller proportion of respondents, 8% (N=18), are 51 years old or older, while the youngest age group, 18-23 (N=9), represents only 4% of the sample.

The predominance of respondents in the 24-35 age group indicates a significant number of young and potentially tech-savvy educators in the survey. Their perspectives and openness to emerging technologies like BIM can be instrumental in shaping the future of architectural education and its alignment with the evolving trends in the AECO sectors. Their familiarity with digital tools and willingness to embrace innovative teaching methods can contribute to integrating BIM into educational curricula and preparing students for the modern AECO sectors.

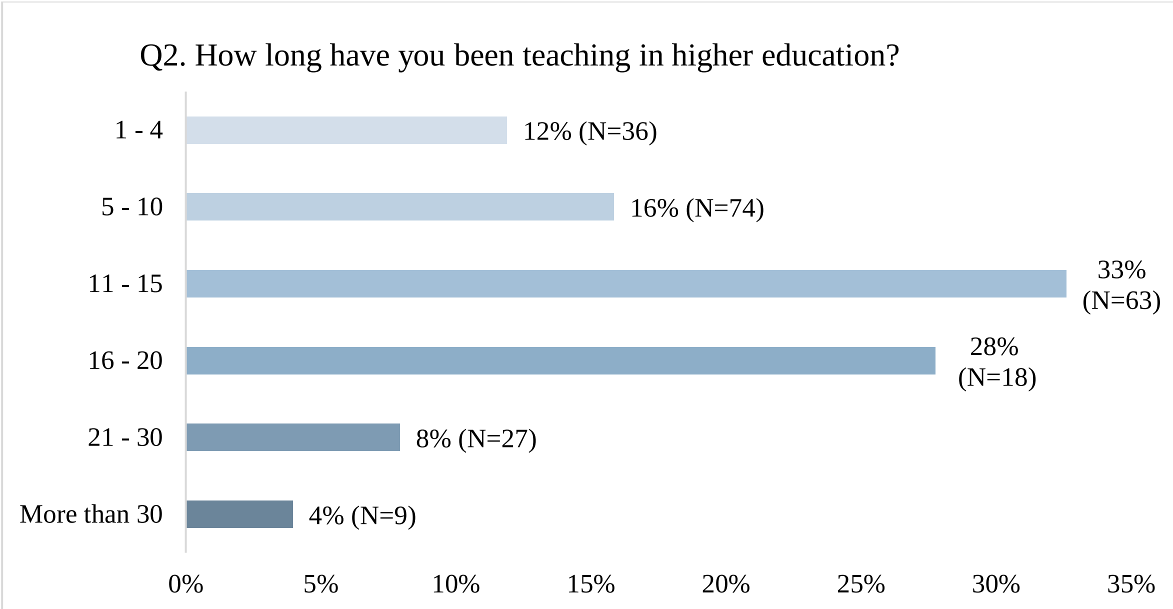

Figure 6.2: Teaching experiences of participants in Survey B.

Teaching experiences (Q2). **Figure 6.2** shows the various range of teaching experiences among participants in Libyan architectural education. A significant number of educators have over a decade of experience teaching in higher education, with 33% (N=74) teaching for 11-15 years and 28% (N=63) teaching for 16-20 years. In addition, a considerable number of relatively newer educators are also present with 16% (N=27) of respondents teaching for 5-10 years and 12% (N=36) of the respondents having teaching experience ranging from 1-4 years. While 8% (N=18) of the participants reported teaching for 21-30 years, and 4% (N=9) of the respondents mentioned having taught in higher education for more than 30 years.

These results illustrate a broad range of teaching experiences within the participant group, ranging from relatively new educators to those with extensive careers in Libyan higher education. This variety in teaching backgrounds can contribute to a well-rounded perspective on the integration of technologies such as BIM into architectural education, taking into account both traditional and innovative teaching approaches.

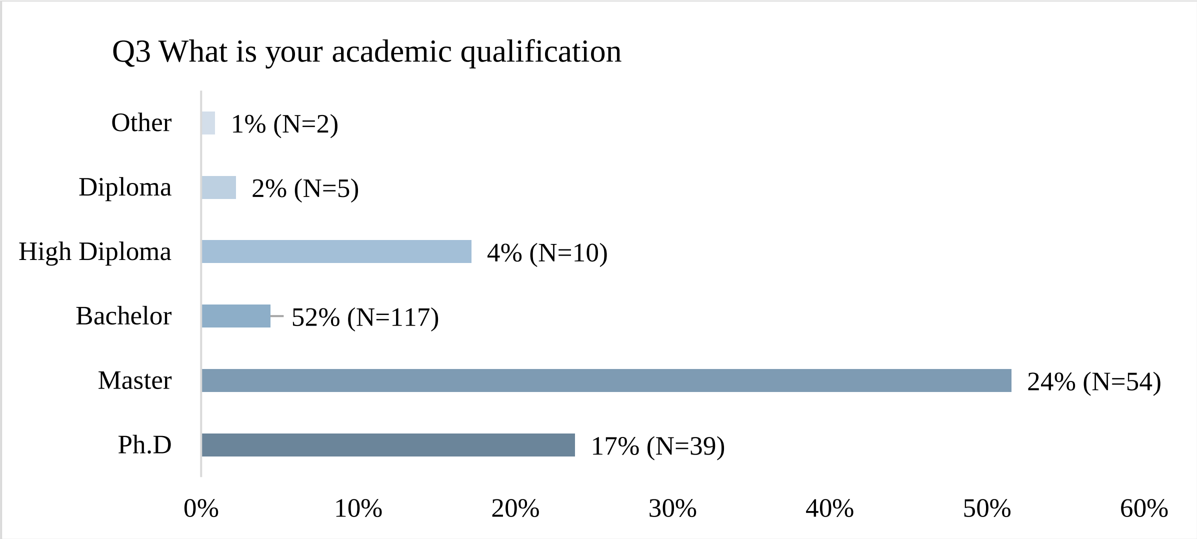

Figure 6.3: Qualification of participants in Survey B.

Qualification (Q3). **Figure 6.3** shows the educational backgrounds of the survey respondents and their potential implications for the adoption of BIM in architectural education. A substantial 52% (N=117) of respondents held a master's degree, and 24% (N=54) of respondents had completed a PhD, representing most of the participant group. In addition, 17% (N=39) of respondents held a higher diploma, showcasing a notable percentage of individuals with specialized diploma-level education. In contrast, a smaller proportion of respondents reported having a bachelor's degree (4%) or a diploma (2%) as their highest qualification.

The prevalence of higher education qualifications among the survey participants suggests a commitment to professional development and expertise, which can be relevant for the adoption of BIM in architectural education. Educators with advanced degrees are more likely to have the necessary knowledge and skills to integrate BIM into their teaching practices and to prepare students for the modern AECO workforce. In addition, the educational background of the respondent group is diverse and reflects a high level of academic achievement. This is a positive development, as it shows that the survey findings are based on the perspectives of highly qualified and experienced educators.

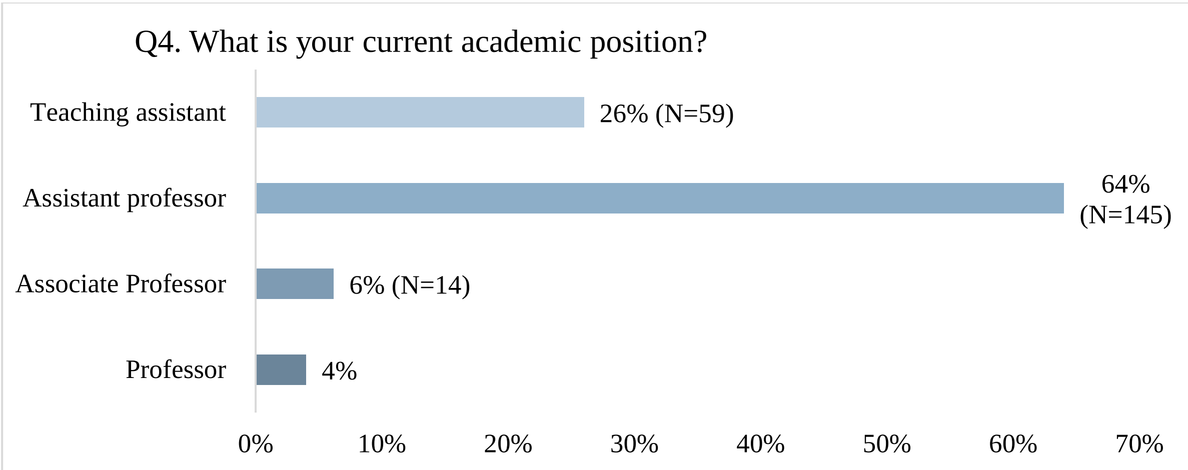

Figure 6.4: Academic position of participants in Survey B.

Academic position (Q4). **Figure 6.4** shows the essential characteristics of the participant group, which have implications for the study's context and findings. The majority of survey respondents held the position of assistant professor or lecturer, accounting for 64% (N=145) of the total. Additionally, 26% (N=59) of respondents were teaching assistants, further underscoring the academic orientation of the participant pool. In contrast, a smaller percentage of respondents occupied higher academic positions, with only 4% (N=9) being professors and 6% (N=14) being associate professors.

These findings carry two significant implications. Firstly, they emphasize the prevalence of lecturer positions among the respondents, suggesting that the majority of participants are actively involved in teaching and educational roles. This is relevant because it implies that the views and opinions of educators, particularly lecturers, are well-represented in the study.

Secondly, the distribution of academic positions highlights the extensive teaching experience within the surveyed group. Many participants have spent considerable time teaching in their specialized fields, which shows they possess valuable insights into academic teaching, readiness, and performance. Their experiences can offer informed perspectives on BIM education and its integration within educational settings.

The distribution of academic positions among the respondents underscores the prevalence of lecturers and highlights the depth of teaching experience within the participant group, enhancing the credibility and relevance of their contributions to the study's objectives.

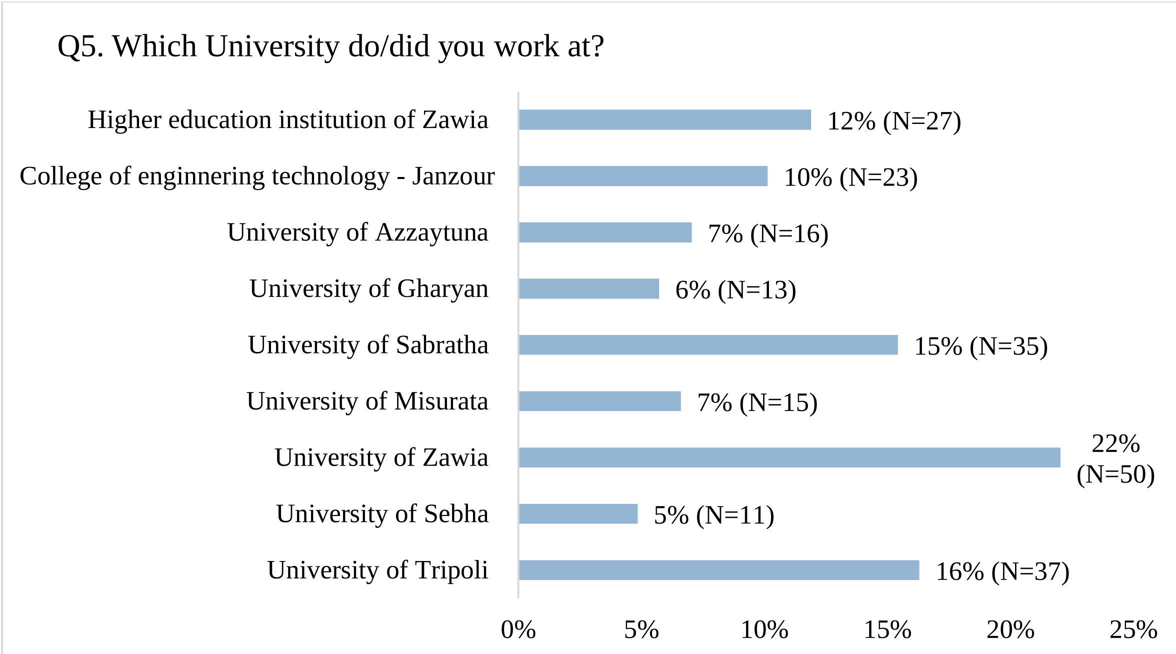

Figure 6.5: Workplace of participants in Survey B.

Workplace (Q5). The results show that respondents from 9 universities were participants in this study, as shown in **Figure 6.5**, 22% (N=50) of respondents worked or still worked at the University of Zawia, whereas 16% (N=37) of respondents out of the sample size did work at the University of Tripoli. The lowest number of respondents, 5% (N=11), had worked with the University of Sabha.

These findings underline the diversity of the participant group, with respondents confirming from a total of nine different universities. This variety encompasses perspectives from various academic institutions and cities within Libya. As a result, the study benefits from a wide range of viewpoints and experiences, enhancing the comprehensiveness of the perceptions obtained. The representation of respondents from different universities and cities adds depth to the study's findings, allowing for a broader understanding of the state of BIM education and its adoption across various academic settings in Libya. This diversity contributes to the applicability of the research outcomes to a wider context.

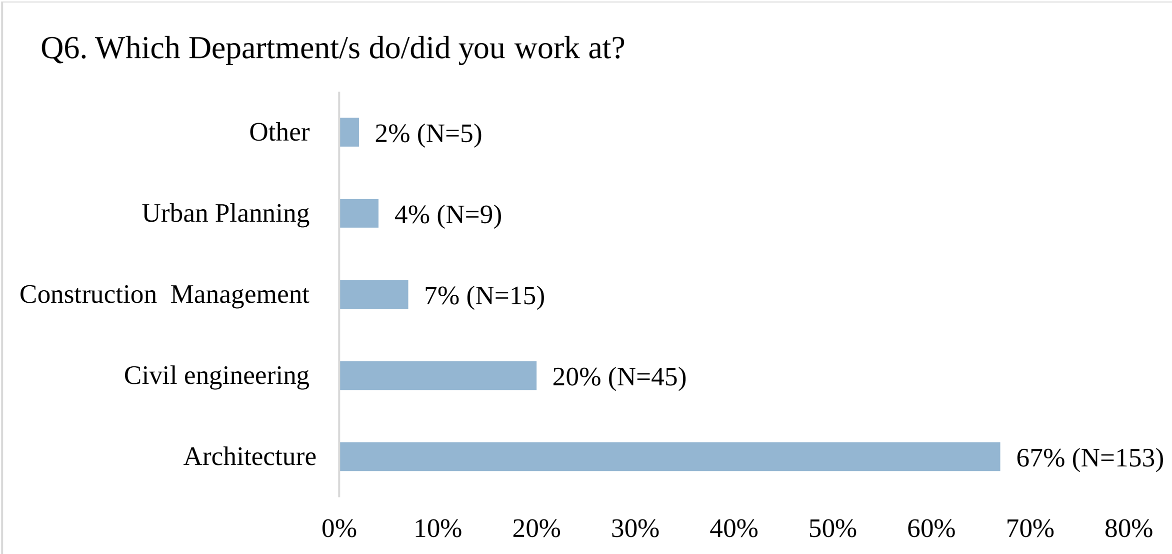

Figure 6.6: Participants related to the department in Survey B.

Department (Q6). **Figure 6.6** shows that a significant majority of respondents, accounting for 67% (N=153) were affiliated with the Architectural department. Furthermore, the survey also included participants from other academic departments with 20% (N=45) of respondents originating from Civil Engineering and 7% (N=15) from Construction Management. In addition to these significant departments, smaller percentages of respondents, comprising 4% (N=9) who have worked or are currently working in Urban Planning, and 2% (N=5) who selected "Other" options.

The substantial representation within the Architectural department is notable as it aligns with the study's primary focus on BIM implementation within architectural education. Consequently, the study benefits from the perspectives of individuals deeply embedded in the field of architecture, ensuring relevance and accuracy in addressing BIM-related issues within this academic context. In addition, the distribution of respondents across various academic departments enhances the study's perceptions by incorporating a range of perspectives from different areas of expertise within the AECO sectors. This diversity enhances the applicability of the research findings in addressing BIM education implementation from multiple viewpoints.

6.6.2 Part 2: The Use of Digital Technologies

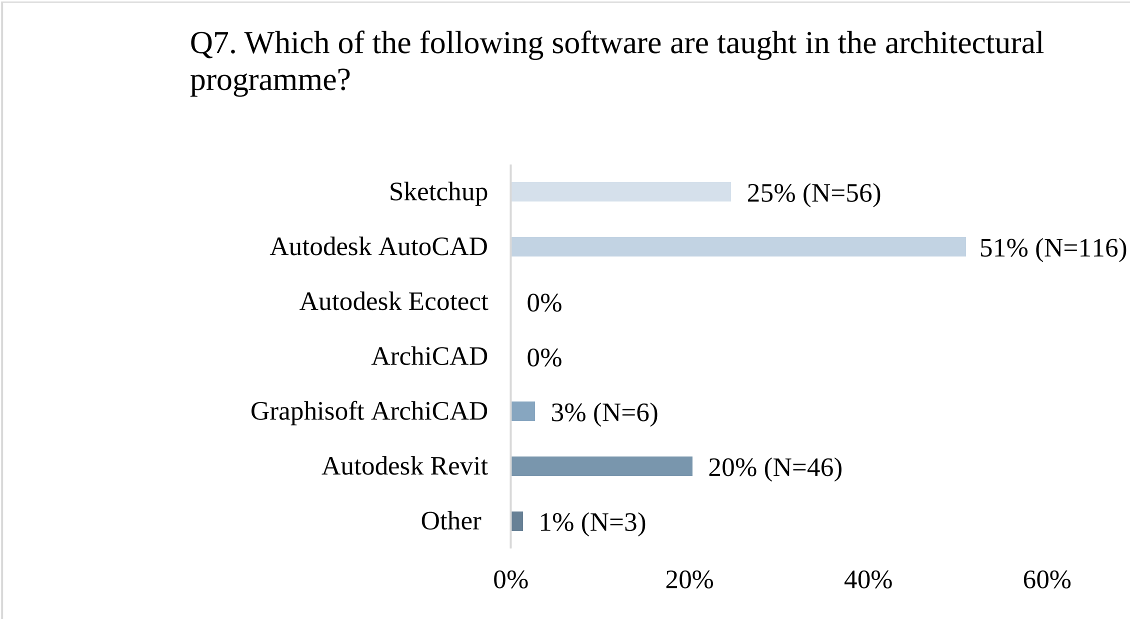

Figure 6.7: Teaching software in architectural education by participants in Survey B.

Teaching software (Q7). **Figure 6.7** shows the software applications commonly taught in architectural programmes, providing valuable visions into the educational background of AECO education. According to the results, Autodesk AutoCAD tools emerge as the most popular software taught in architectural programmes, with 51% of respondents (N=116) indicating its prominence. This observation aligns with previous research, as studies by Eadie et al. (2016), Nushi and Basha-Jakupi (2017), and Maina (2018) have emphasised the significance of AutoCAD in architectural education.

SketchUp emerges as the second most taught software, with 25% of respondents (N=56) adopting its use in architectural programmes. SketchUp's position highlights the growing importance of 3D modelling within architectural education, as it equips students with the skills to create 3D visualizations and models.

Autodesk Revit, as the main BIM software, is also notable, with 20% of respondents (N=46) indicating its existence in architectural programmes. This reflects the increasing recognition of BIM as a fundamental aspect of modern architectural practice, and its incorporation into education prepares students for the industry's evolving needs. In contrast, Graphisoft ArchiCAD appears to have a more limited adopt, with only 3% of respondents (N=6) mentioning its use in architectural programmes.

These results confirm the educational trends in the architectural programmes, showcasing traditional 2D drafting tools like AutoCAD as the predominant choice for teaching in architectural programmes, mirroring their widespread use in architectural practice. In addition, architectural education evolves with the integration of 3D modelling and BIM tools to align with the evolving demands of the AECO sectors (Sampaio, 2014; NATSPEC, 2019; Shibani et al., 2020). The research supports the idea that architectural education is adapting to meet the AECO sector's needs by encompassing advanced digital technologies in its curriculum.

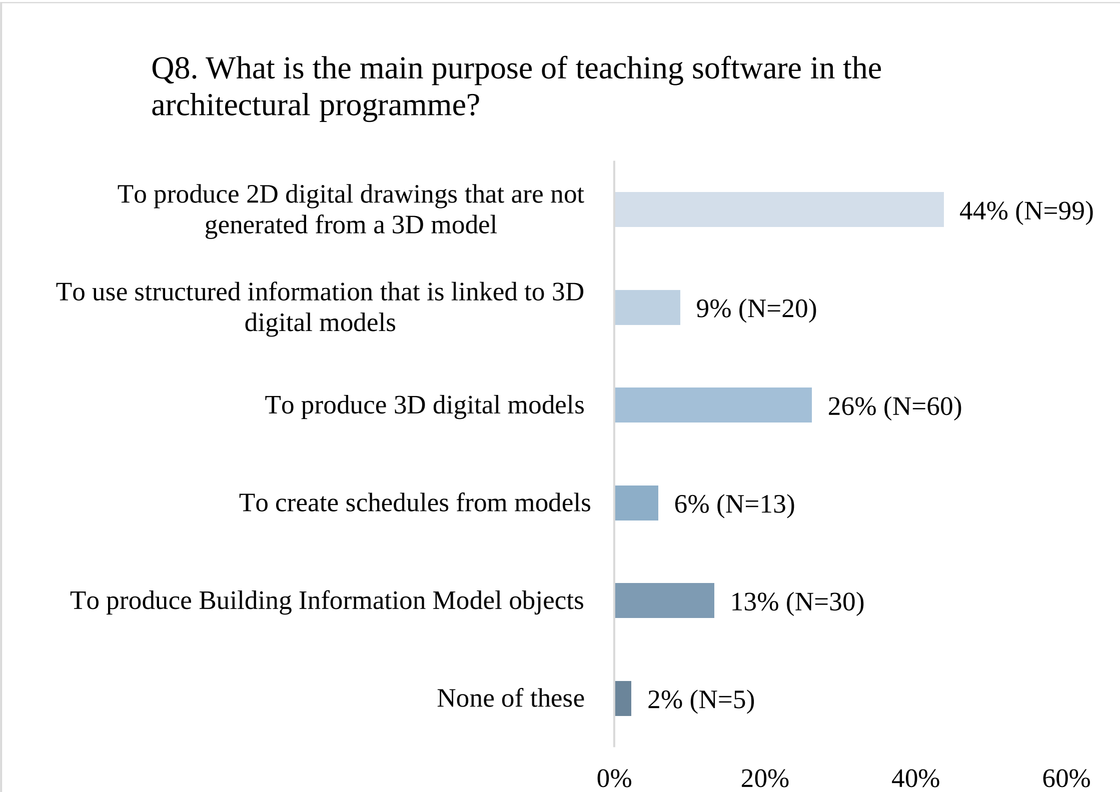

Figure 6.8: Purpose of teaching software by participants in Survey B,

Purpose of teaching software (Q8). **Figure 6.8** illustrates the primary purpose of teaching tools in the architectural programme. The majority of respondents, accounting for 44% (N=99) of respondents stated that producing 2D digital drawings that are not generated from a 3D model is the primary purpose. This finding emphasises equipping students with the skills required for conventional 2D drafting methods.

In contrast, 26% of respondents (N=60) indicated that the primary focus of teaching tools is to enable the generation of 3D digital models. This highlights the growing importance of 3D modelling in architectural education. Moreover, 13% of the participants (N=30) mentioned that the primary purpose of teaching tools is to aid in producing building information model objects. This points to a recognition of the increasing significance of BIM in contemporary architectural practice.

The results demonstrate that there is no singular approach to the primary purpose of teaching software tools in architectural programs. Instead, it reflects the traditional 2D drafting skills with 3D modelling and BIM models, showcasing a different approach to architectural education. This approach reflects the evolving demands and technologies within the field of architectural, as noted in the study of Aljad (2023). It emphasises the importance of preparing students with a different skill set in contemporary architectural practice, where various methods and tools exist.

6.6.3 Part 3: BIM Awareness, Importance, and Responsibility

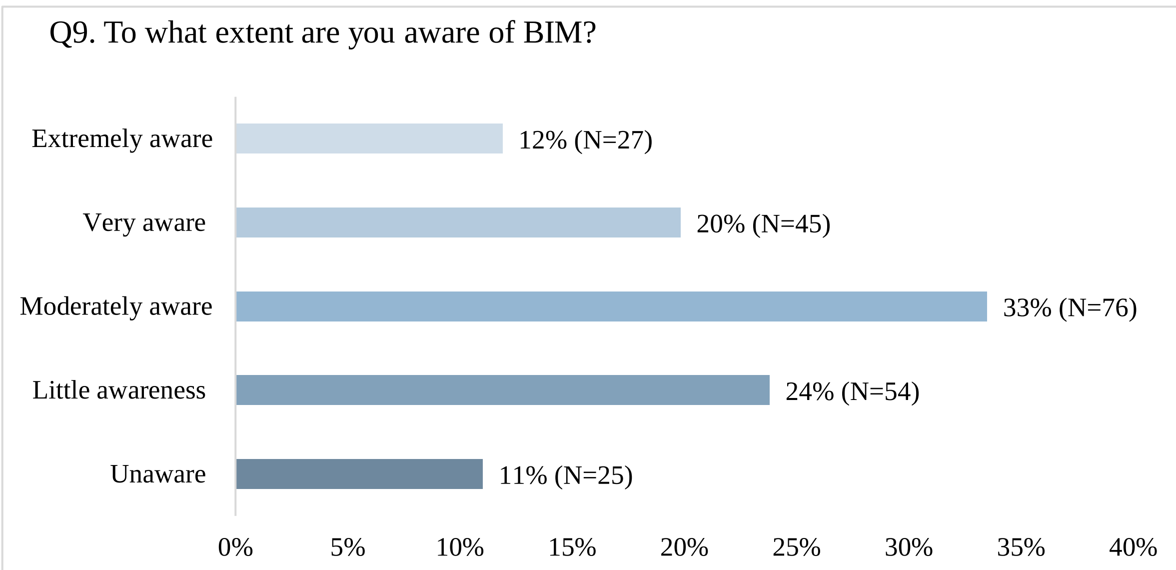

Figure 6.9: level of BIM awareness among participants in Survey B.

BIM awareness (Q9). **Figure 6.9** shows the BIM awareness level between participants in Libyan architectural education. A significant number of respondents 33% (N=76) stated that they were moderately aware of BIM, and 24% (N=54) mentioned having little awareness. On the positive side, 20% (N=45) of respondents reported being very aware of BIM, and 12% (N=27) indicated being extremely aware. These individuals likely have a good grasp of BIM concepts and technologies. In contrast, only 11% (N=25) of respondents were unaware of BIM, underscoring the need for urgent awareness campaigns and educational initiatives. BIM is a transformative technology in the AECO sectors, and educators should be well-informed about its principles and applications to effectively prepare students for the workforce.

These findings are consistent with the studies made by Maharika et al. (2020) and Böes et al. (2021), who have pointed out the existence of a significant gap in BIM awareness within academic institutions. This issue is not unique to Libyan architectural education but is a broader challenge faced by educational institutions globally.

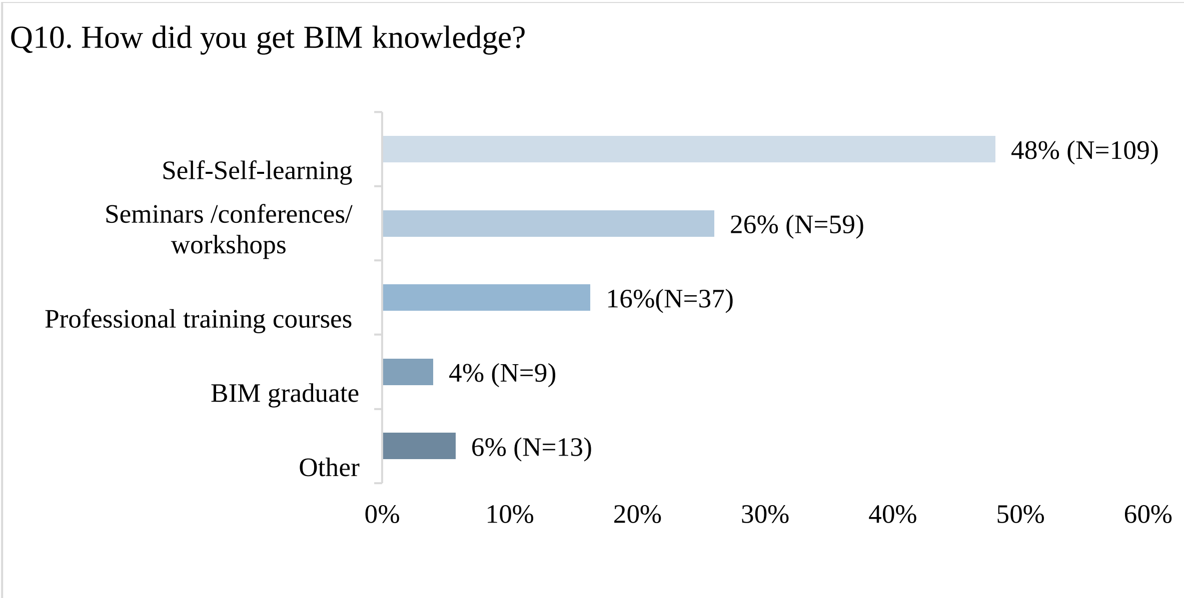

Figure 6.10: The method of BIM knowledge acquisition by participants in Survey B.

BIM knowledge acquisition (Q10). On asking respondents how they got BIM knowledge, as presented in **Figure 6.10**. A substantial majority of respondents, comprising 48% (N=109), indicated that they acquired BIM knowledge through self-learning. In comparison, 26% (N=59) of respondents mentioned that they gained BIM knowledge through seminars and conferences. In contrast, 16% (N=37) of respondents reported that they acquired BIM knowledge through professional training courses. A smaller percentage, representing 4% (N=9) of participants, stated that they are BIM graduates. In addition, 6% (N=13) of respondents mentioned "other" options for acquiring BIM knowledge, suggesting a range of alternative methods that were not explicitly covered in the predefined categories.

These findings indicate that there is a need for more comprehensive and structured BIM education and training opportunities for educators. The predominance of self-learning implies that educators are taking the initiative, but a more organised approach to BIM education within academic institutions may be necessary to ensure that educators have the essential knowledge and skills to effectively teach BIM to students. Additionally, efforts to increase awareness and accessibility of BIM education among educators could help bridge the gap between BIM knowledge and its application in architectural education and practices.

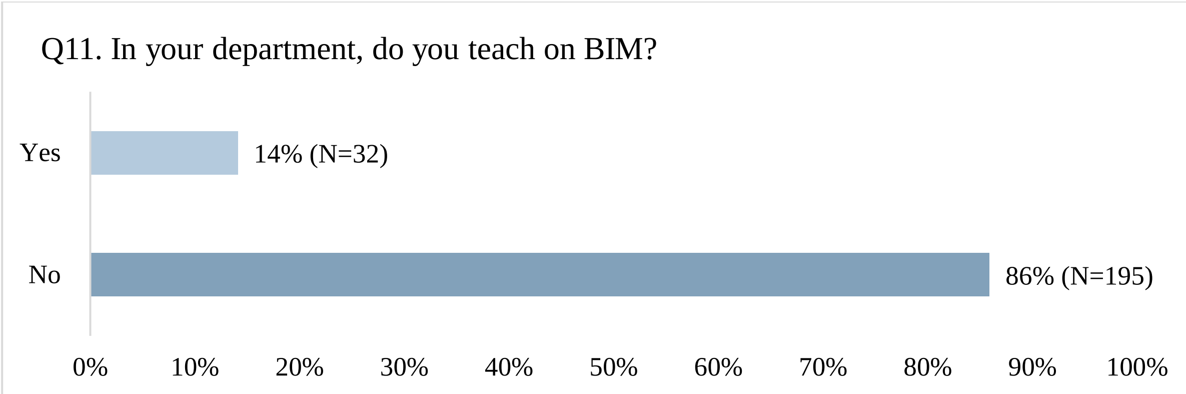

Figure 6.11: Teaching BIM at the architectural department by participants in Survey B.

Teaching BIM (Q11). **Figure 6.11** indicates that there is a significant gap in the adoption of BIM as a teaching component within academic institutions in the context of architectural education and related disciplines in Libya. The data reveals that a substantial majority, comprising 86% (N=195) of respondents, do not teach BIM, while only 14% (N=32) acknowledge that they teach BIM.

This finding highlights the imperative for academic institutions to embrace BIM education in architectural curricula. These perceptions are consistent with previous research in the domain of BIM integration within architectural education. Studies by Ghosh et al. (2013), Silverio et al. (2016), and Casasayas et al. (2021) have emphasized the importance of incorporating BIM into architectural curricula, as it aligns with industry needs and prepares students for the demands of the modern AECO sectors.

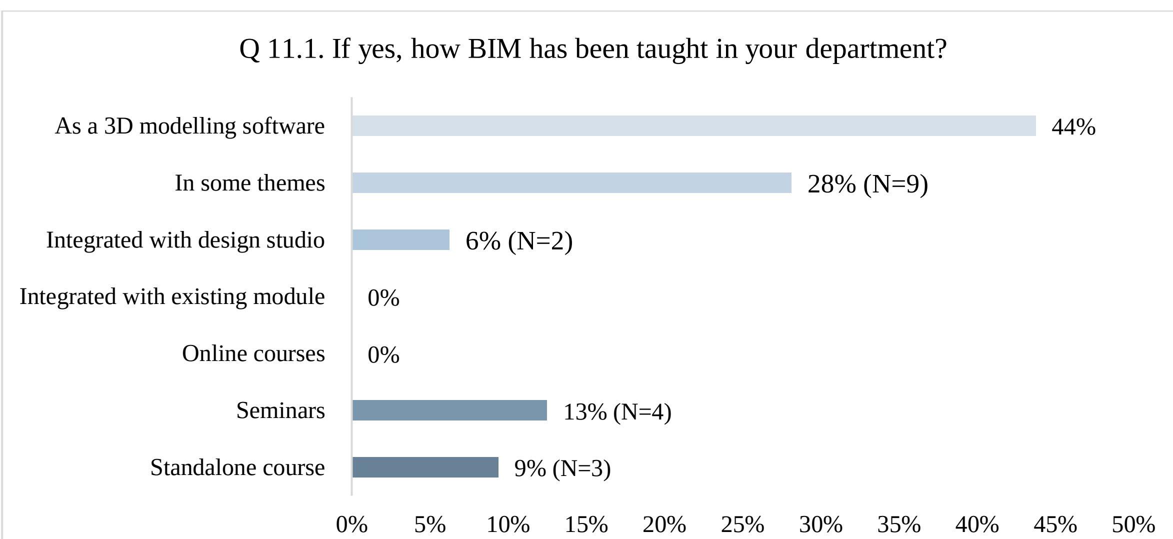

Figure 6.12: The method of teaching BIM by participants in Survey B.

BIM teaching experience (Q11.1). This is a conditional question if respondents answered yes for Q11. This question got a total of 32 respondents who previously stated that they teach BIM. **Figure 6.12** shows that the majority, comprising 44% (N=14) of respondents, mentioned that BIM is introduced in their department as a 3D modelling software. This finding aligns with the common implementation of BIM for 3D modelling within architectural programs, as observed by Hossain et al. (2022).

In addition, 28% (N=9) of respondents stated that BIM is discussed within specific themes or topics. This indicates that BIM concepts and principles may be integrated into course content rather than being the focus of dedicated courses. 13% (N=4) of respondents stated that BIM is taught through seminars. Seminars may provide targeted and focused instruction on BIM-related topics.

The relatively lower percentage of 9% of respondents indicating a standalone course for BIM teaching suggests that dedicated courses focused especially on BIM are less common among surveyed educators. This finding differs from the recommendations of Abdirad and Dossick (2016), who emphasized the need for dedicated BIM courses in architectural programmes. It indicates potential opportunities for expanding the presence of such courses to provide students with more comprehensive BIM knowledge.

The results from this study indicate that BIM teaching methods and approaches in architectural education. While there is a predominant emphasis on BIM as a 3D modelling tool, there is the possibility of expanding the existence of standalone BIM courses to offer students a deeper understanding of BIM concepts and applications. The integration of BIM into design studios and broader course content aligns with the idea of BIM as an integral part of architectural education and showcases the adaptability of BIM teaching methods (Coates et al., 2018; Labib and Nagy, 2020).

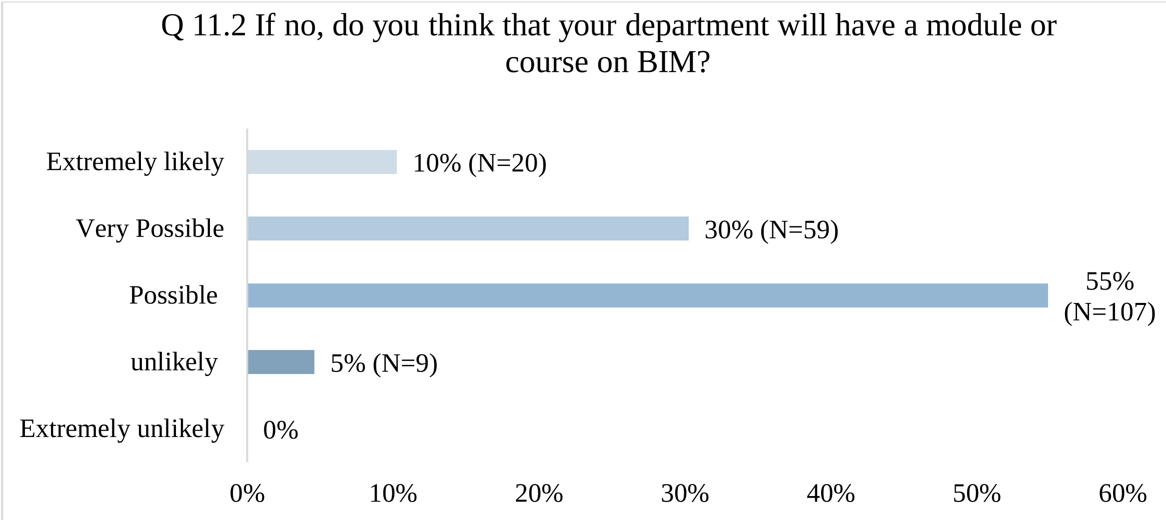

Figure 6.13: The Possibility of teaching BIM at the architectural department, according to participants in Survey B.

Possibility of teaching BIM (Q11.2). This is a condition question if respondents answered no for Q11. Previously, the results showed that 86% (N=195) of educators do not teach BIM. **Figure 6.13** shows that 55% (N=107) of respondents declared that possibly their department would have a course on BIM, 30% (N=59) stated that it was very possible about the course, 10% (N=20) were extremely likely, and only 5% (N=9) of respondents were unlikely that their department would integrate BIM education. The results indicate that participants are willing to have a BIM course in their departments.

These findings indicate a positive attitude among respondents regarding the possibility of introducing a BIM course in their departments. The majority expressed some level of optimism, ranging from possibly to extremely likely, that their departments would consider offering BIM education in the future. This reflects a willingness to embrace BIM education within academic institutions, which is a positive sign for the potential integration of BIM into architectural education in Libya.

The relatively low percentage (5%) of respondents who were “unlikely” to see their department offering a BIM course suggests that there is still some resistance or uncertainty in a small portion of respondents. However, the overall response leans toward openness to future BIM course offerings, which aligns with the broader acknowledgement of BIM's relevance in architectural education (as indicated in previous questions). These results imply that there is potential for the expansion of BIM education in academic institutions, but it may require support, curriculum development, and resource allocation to make it a reality.

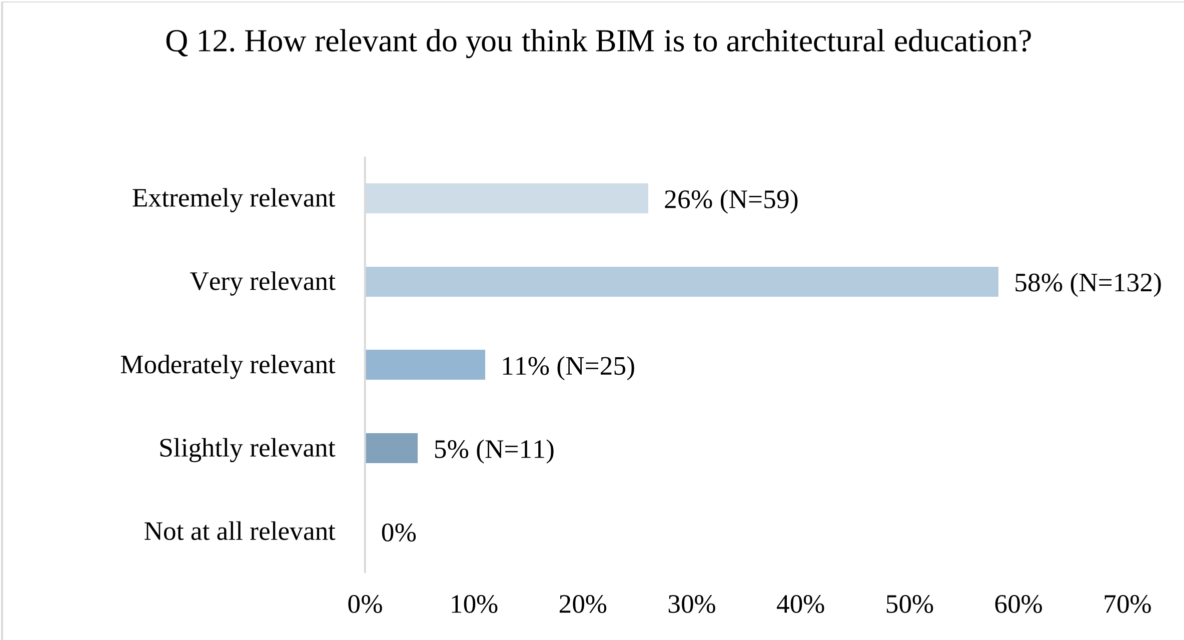

Figure 6.14: The relevance of BIM to architectural education according to participants in Survey B.

Relevance of BIM (Q12). **Figure 6.14** reflects a strong consensus among respondents regarding the relevance of BIM within architectural education. A substantial majority of respondents, comprising 58% (N=132), indicated that they believe BIM is very relevant to architectural education along with an additional 26% of respondents stating that BIM is extremely relevant. These responses demonstrate a widespread recognition among participants that BIM plays a highly relevant and integral role in the context of architectural education in Libya.

11% (N=25) of respondents considered BIM to be moderately relevant, reflecting an acknowledgment of its importance but with a somewhat less certain stance. And only 5% of respondents expressed that BIM is slightly relevant to architectural education. This represents a minority perspective within the surveyed population.

These survey results highlight the widespread recognition of BIM as highly relevant to architectural education in Libya. This consensus shows the importance of incorporating BIM-related content into architectural programmes, supporting the idea that BIM is not just a tool but an essential and integral component of architectural education and practice. These findings are consistent with the findings of previous research in the field of BIM education. Studies by Isanović and Çolakoğlu (2020) have also highlighted the significance of BIM as a relevant and essential component of architectural education, aligning with AECO needs and preparing students for the evolving demands of the AECO sectors.

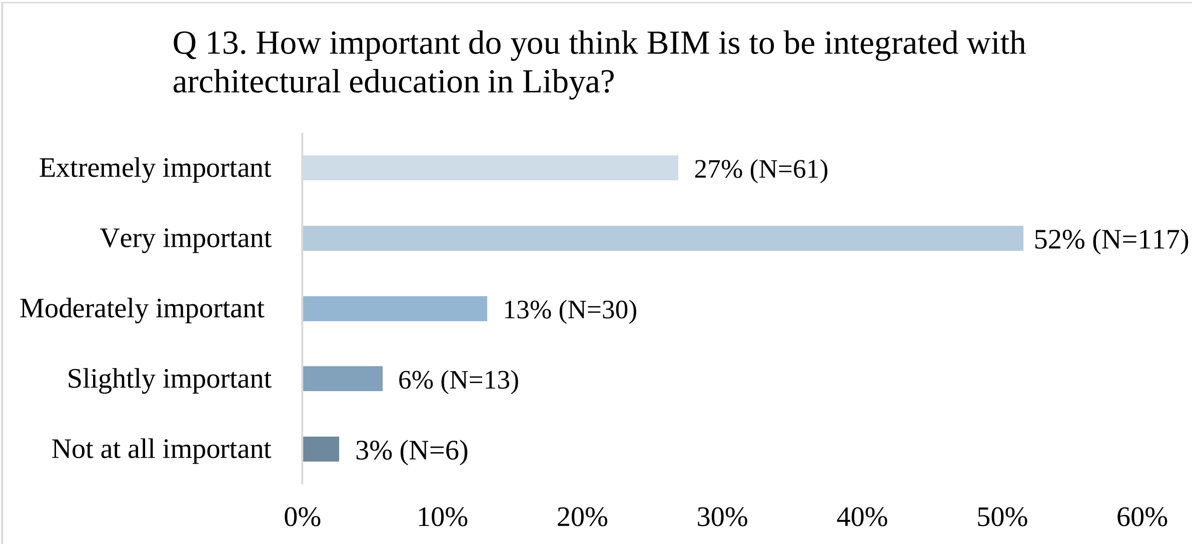

Figure 6.15: The importance of BIM integration with architectural education, according to participants in Survey B.

The importance of BIM education (Q13). **Figure 6.15** highlights the consensus among respondents regarding the significance of incorporating BIM into the academic curriculum. The majority of respondents, accounting for 52% (N=117), indicated that they believe it is very important for BIM to be integrated with architectural education along with an additional 27% (N=61) of respondents expressed that it is extremely important. These responses show a strong opinion among participants that BIM holds substantial value and relevance within the context of architectural education.

Also, 13% (N=30) of respondents believed that it is moderately important, indicating a recognition of the importance of BIM education but with a somewhat less certain stance. While only a small minority of respondents, comprising 6% (N=13), considered BIM integration to be slightly important, a mere 3% (N=6) indicated that it is not at all important. These responses represent a minority perspective within the surveyed population.

The survey results show a strong belief among the majority of respondents regarding the importance of incorporating BIM into architectural education. This viewpoint shows the recognition of BIM as an essential and integral component of modern architectural practice and the need for architectural programmes to incorporate BIM-related coursework (Hossain and Bin Zaman, 2022).

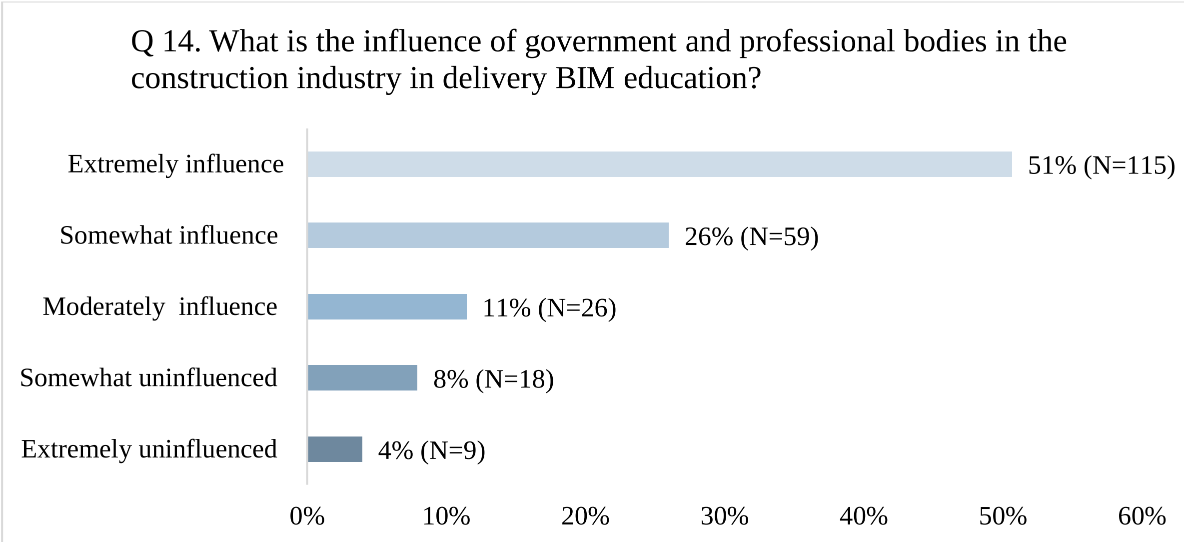

Figure 6.16: The influence of government and professional bodies in BIM education delivery, according to Survey B participants.

Government and professional bodies influence the delivery of BIM education (Q14). The results presented in **Figure 6.16** indicate that 51% (N=115) of respondents mentioned it is extremely influential for government and professional bodies in the AECO sectors in delivering BIM education. 26% (N=59) believe that it is somewhat influenced, 11% (N=26) mentioned that it is moderately influenced, about 8% (N=18) stated that it is somewhat uninfluenced, and only 4% (N=9) of respondents believed that it is extremely uninfluenced.

This result shows the prevailing response among respondents that government and professional bodies have substantial influence in shaping the delivery of BIM education within the AECO sectors (Yusuf et al., 2017). It highlights the importance of collaborative efforts between these entities and educational institutions to ensure that BIM education aligns seamlessly with AECO standards and best practices. These collaborative efforts are crucial for promoting the preparation of students for the realities of the modern AECO workforce. The findings align with the recommendations of Mihindu and Farzad (2021) regarding the need for strong cooperation between government, professional bodies, and educational institutions to ensure that BIM education is aligned with AECO needs and standards.

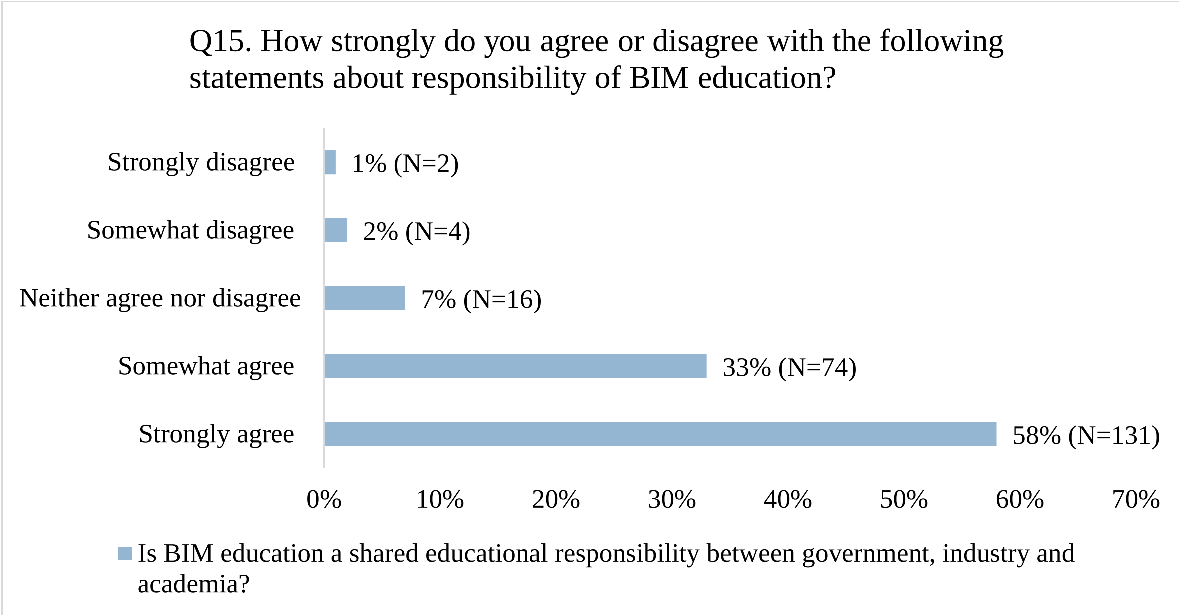

Figure 6.17: BIM education shares responsibility between stakeholders, according to participants in Survey B.

BIM education responsibility (Q15). **Figure 6.17** shows that a substantial portion of participants approve of the vision that BIM education is a shared responsibility by both government and academia. 58% (N=131) of respondents express strong agreement, and 33% (N=74) agree with this statement. In contrast, 7% (N=16) neither agree nor disagree, while 2% (N=4) and 1% (N=2) of participants hold a dissenting view.

These findings highlight a prevailing consensus among the respondents that BIM education should be a collaborative effort involving both government and academia, aligning with the observations made by Sampaio (2021). Given this perspective, there emerges a clear need to establish formal partnerships between government organizations and academic institutions to advance the cause of BIM education. This collaboration would enable the sharing of resources, and expertise to ensure that BIM education aligns effectively with industry needs and standards, providing students with the best possible preparation for the AECO sectors.

6.6.4 Part 4: Teaching and Learning Strategies for BIM Education

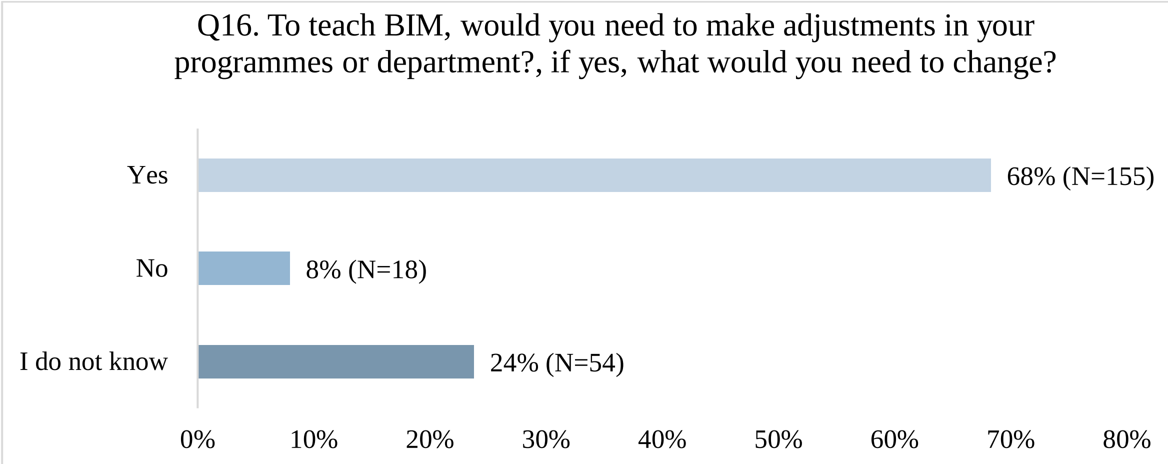

Figure 6.18: Programme adjustments are needed to teach BIM, according to participants in Survey B.

Programmes adjustment (Q16). When asking respondents if they would need to make adjustments in their programmes or departments to teach BIM. **Figure 6.18** shows that 68% (N=155) responded with Yes, indicating that most participants favour incorporating BIM into their educational programmes. This shoes a willingness to adapt and evolve their existing curriculum and departmental practices to include BIM-related content.

Furthermore, 24% (N=54) of respondents stated, I do not know, possibly reflecting a need for further information or resources to make an informed decision regarding BIM integration. only 8% (N=18) of respondents mentioned No, indicating that a small minority believe adjustments may not be necessary for their programmes or departments.

The most common rationale cited by respondents for requiring adjustments concerns curriculum and educational materials. Respondents acknowledged the necessity of updating the curriculum and acquiring educational materials suitable to BIM. This ensures that students have access to relevant resources specifically designed to support their BIM studies (Maina, 2018; Maharika et al., 2020). These findings underline the significance of preparedness and the need for institutions to stay current in terms of curriculum and materials to meet the demands of BIM education effectively.

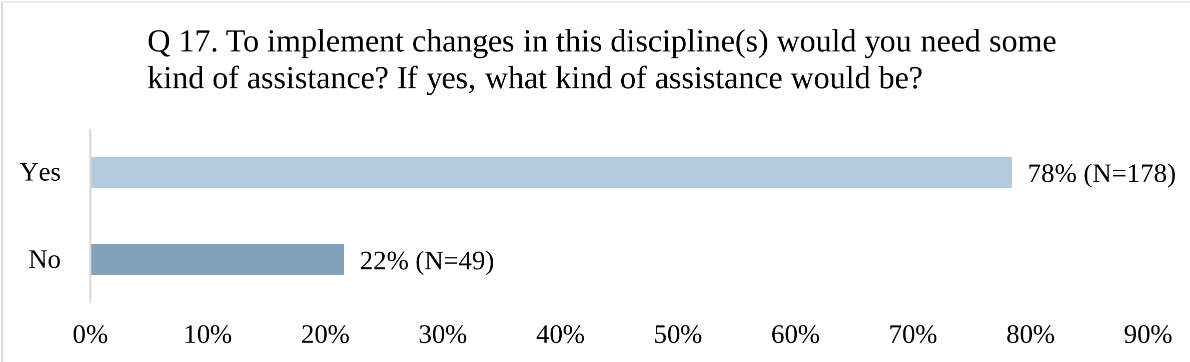

Figure 6.19: Assistance needs to teach BIM, according to participants in Survey B.

Assistance needs (Q17). When asking respondents if they need any assistance implementing changes in this discipline, 78% (N=178) stated yes, while only 22% (N=49) of respondents mentioned no, as shown in **Figure 6.19**. This indicates that the implementation of BIM education is a complex process that requires guidance and support.

The types of assistance needed vary, but some common help noted by respondents include.

- Develop standards and guidelines. Many respondents requested standards guidance to promote BIM and to ensure consistency of BIM education purpose among educators. This can help to reduce the complexity and costs of BIM implementation.
- Expertise from BIM professionals: Many respondents noted that they need help from experienced BIM professionals to develop a good programme, set up workshops and seminars, and teach BIM effectively.
- Support from IT: Respondents also emphasized the importance of IT support in implementing BIM, as it requires specialized hardware, software, and infrastructure.
- Training for faculty and staff: Many respondents noted that they need to be trained on BIM software and teaching methods to effectively deliver BIM education to students.
- Financial support: Many respondents requested financial support as BIM software licenses, hardware, and educational materials can be expensive, so institutions need financial support to implement BIM effectively.
- Curriculum: Many respondents requested guidance and support in designing or updating their curriculum to integrate BIM-related courses effectively.

In addition to these common needs, respondents provided additional suggestions, such as industry collaboration, research opportunities, and promotional support, as ways to enhance their BIM education efforts. These align with previous studies, such as those by Maharika et al. (2020) and Abdirad and Dossick (2021). These studies emphasize the importance of human resources management, physical infrastructure, and adequate financial resources to finance BIM education in higher education institutions. It is clear that respondents are aware of the substantial efforts and resources required to effectively integrate BIM into their educational programmes.

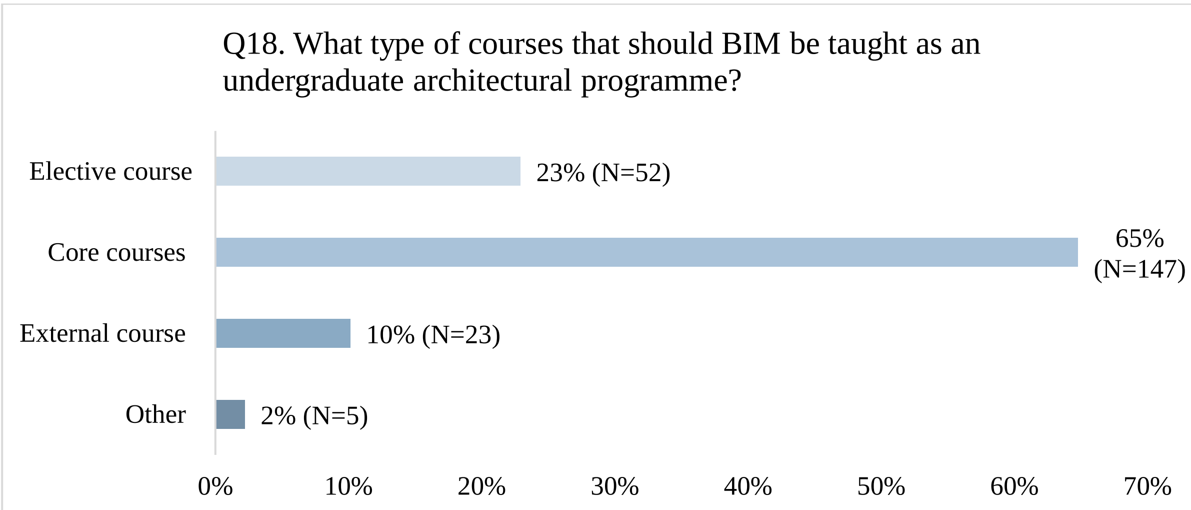

Figure 6.20: BIM course types according to participants in Survey B.

Course types (Q18). **Figure 6.20** shows a consensus among respondents regarding the ideal approach to incorporating BIM education into academic curricula in Libya. The majority of respondents, constituting 65% (N=147), expressed the view that BIM should be taught as a core course. A smaller proportion of respondents, representing 23% (N=52), suggested that BIM should be offered as an elective course. A minority of respondents, comprising 10% (N=23), advocated for BIM to be offered as an external course.

The survey results highlight the prevailing viewpoint among participants that teaching BIM as a core course is the most favourable approach for incorporating BIM education into academic curricula. This perspective highlights the essential role of BIM education and its fundamental importance within the fields of architecture, engineering, and construction. It underlines the need to ensure that BIM is a mandatory and comprehensive part of the educational experience for all AECO students, aligning with previous research findings (Sanchez-Lite et al., 2022).

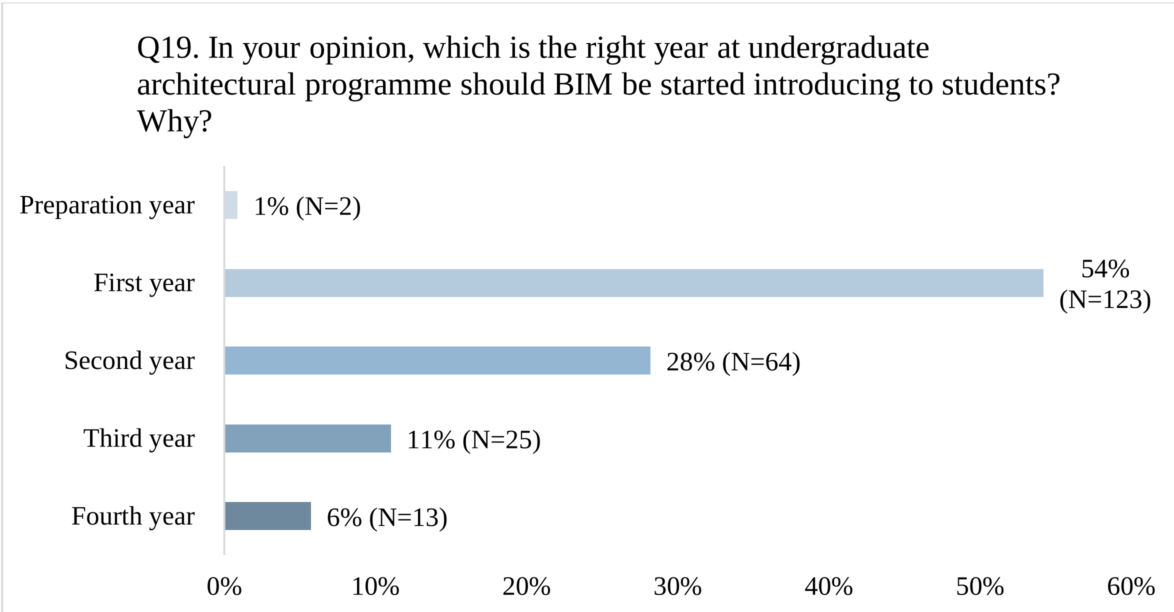

Figure 6.21: BIM education starting the year, according to participants in Survey B.

Year for starting to introduce BIM and Why (Q19). **Figure 6.21** shows that most respondents (54%, N=123) believe BIM education should be introduced in the first year of the architectural programme, indicating a consensus in favour of integrating BIM principles and tools right from the beginning of students' academic journey.

The rationale for introducing BIM in the first year aligns with the idea that early exposure to BIM technology can have several advantages, as indicated by respondents' comments:

- Seamless integration: By introducing BIM from early years, students can seamlessly integrate BIM principles and tools into their architectural education. This gradual approach allows them to build a strong foundation in BIM (Boton et al., 2018).
- Familiarity with industry practices: Early exposure to BIM aligns students with industry practices, as BIM is widely used in the architecture, engineering, and construction sectors. This familiarity can enhance students' readiness for internships and future careers.
- Progressive learning: Starting teaching BIM in the early years enables students to progressively build their BIM skills, moving from basic concepts to more advanced applications as they advance in their studies.

In addition, a significant portion of respondents (28%, N=64) also support the idea of introducing BIM in the second year. This still represents early exposure to BIM but allows students first to establish a foundational understanding of architectural principles.

However, fewer respondents 11%, (N=25) for the third year and 6%, (N= 13) for the fourth year suggest introducing BIM education in later years of the programme. This approach may assume that students need a more comprehensive understanding of architecture before diving into BIM. And only a very small percentage (1%, N=2) of respondents propose introducing BIM in the preparation year. This approach suggests that students should first focus on preparatory coursework before engaging with BIM concepts.

The choice of when to introduce BIM into the curriculum may vary depending on the specific goals and resources of the educational institution. However, the survey results indicate a strong preference for early exposure to BIM, emphasizing its importance in contemporary architectural education and the benefits of aligning students with industry standards and practices. This aligns with the recommendations of previous research, such as Boton et al. (2018), Chihib et al. (2019) and Sotelino et al. (2020), which emphasizes the advantages of early BIM education integration for students to progressively raise awareness, learn from mistakes.

Table 6.1: BIM teaching strategies according to participants in Survey B

BIM teaching strategies	**Extremely prefer**	**Very prefer**	**Moderately prefer**	**Slightly prefer**	**Not at all prefer**
BIM-focused degree programme	10% 22	16% 36	47% 106	20% 45	8% 18
Seminars, workshops, or conference	20% 45	37% 85	26% 59	14% 31	3% 7
Restructure the current curriculum to integrate BIM	69% 157	21% 47	10% 23	0% 0	0% 0
Combine BIM teaching with online videos	13% 30	28% 63	35% 80	16% 36	8% 18
BIM integrates with existing courses	53% 120	33% 74	13% 30	1% 3	0% 0
BIM used in graduation projects	37% 83	36% 81	19% 42	9% 21	0% 0
BIM integrated with design studio	38% 87	30% 67	24% 55	4% 9	4% 9
BIM standalone courses	29% 65	50% 113	22% 49	0% 0	0% 0
BIM collaboration course with other disciplines	23% 53	28% 63	37% 84	12% 27	0% 0
BIM collaboration course with other universities	12% 27	20% 45	24% 55	32% 73	12% 27

Teaching strategies (Q20). **Table 6.1** shows a different perspective among respondents. There is no one-size-fits-all approach to integrating BIM into education. Many participants favour a balanced strategy that incorporates various methods, aligning with prior research findings that have also indicated a lack of consensus on a single teaching approach for implementing BIM into architectural programmes (Gu and Wang, 2012; Huang, 2019; Govender et al., 2019; Zamora-Polo et al., 2019).

The most prominent preference, with 69% (N=157) of respondents, is the idea of restructuring the current curriculum to integrate BIM. This approach proposes modifying the existing educational framework to incorporate BIM concepts and practices into the core curriculum seamlessly. By restructuring the curriculum, academic institutions can ensure that BIM becomes an integral part of the educational experience for all students, providing a solid foundation in BIM principles.

Additionally, 53% (N=120) of respondents favour the approach of integrating BIM with existing courses. This strategy involves introducing BIM-related content into the coursework of existing classes, thereby exposing students to BIM concepts within the context of their primary academic disciplines. This approach allows students to learn BIM while simultaneously studying their core subjects.

Another significant preference, expressed by 50% (N=113) of respondents, is for Standalone Courses. This approach involves offering dedicated BIM courses that focus exclusively on BIM principles and practices. These standalone courses can cater to students who seek specialized BIM education or wish to deepen their knowledge in this field.

The survey results emphasize the importance of adopting a balanced approach to BIM education. Restructuring the curriculum to integrate BIM, integrating BIM with existing courses, and offering standalone BIM courses all have their merits and can collectively contribute to a well-rounded BIM education ecosystem. Boton et al. (2018) noted that one of the essential aspects of successfully teaching BIM is choosing an appropriate approach, along with expert knowledge and skills. Therefore, the appropriate approach should ensure that students receive a comprehensive education that aligns with their career goals and industry demands while allowing academic institutions to adapt to the evolving landscape of AECO practices.

6.6.5 Part 5: University Readiness and Challenges for BIM Education

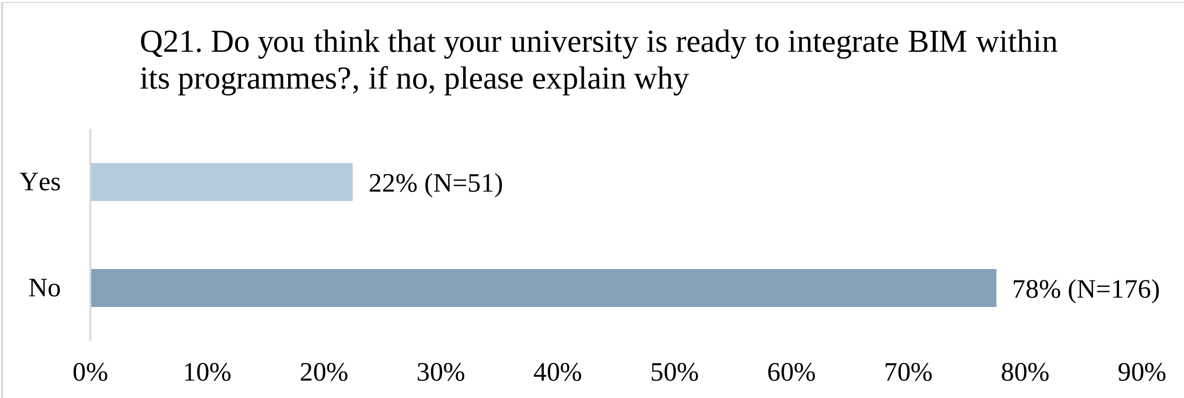

Figure 6.22: Universities' readiness for teaching BIM based on participants in Survey B.

Universities Readiness (Q21). When asking respondents whether they think their university is ready to integrate BIM within its programmes. **Figure 6.22** shows that a significant majority of the participants, 78% (N=176), expressed that their universities are not ready to integrate BIM into their educational programmes. However, the 22% (N=51) of respondents who indicated that their universities are prepared to incorporate BIM may represent a minority of institutions that have made progress in this area.

There are several reasons why a university may not be prepared to incorporate BIM into its curriculum, as explained by respondents, which can be summaries as the following:

- Lack of awareness: The university may not fully understand the benefits of BIM integration or the industry's increasing demand for graduates with BIM skills. It is very important to raise awareness of BIM in architectural education.
- Curriculum development: The current curriculum may not align with BIM integration, and developing or updating the curriculum could be a complex and time-consuming process.
- Lack of resources: the university may not have the necessary resources to support BIM integration. This could include a shortage of BIM software licenses, inadequate technology infrastructure, and limited funding for training and development.
- Lack of faculty expertise: There might be a shortage of proficient faculty members in BIM software. Faculty training and expertise are essential for effective BIM education.

Moreover, (Q22) serves as a valuable tool for assessing university readiness by prompting respondents to evaluate the maturity and readiness of BIM education within their respective institutions. This assessment is based on specific criteria, including the integration of BIM into the university's vision, the availability of relevant software and hardware, facilities, curriculum development, staff development initiatives, and teaching and learning resources.

The findings presented in **Table 6.2** underline a concerning that BIM education has yet to receive the attention and importance it deserves in architectural education in Libya, as the majority of respondents have rated their university's readiness as being at level 0, with only a small minority indicating they have reached level 1 (initial readiness).

These findings point to a significant readiness gap in Libyan universities regarding BIM integration. To address this gap, strategies such as professional development, industry partnerships, access to BIM software and technology, curriculum enhancement, and collaboration with government bodies and professional organizations may be necessary. Bridging this readiness gap is crucial to equip students with the skills and knowledge required for success in the evolving AECO sectors, aligning with global trends in architectural education (Yusuf et al., 2017; Maina, 2018; Maharika et al., 2020; Böes et al., 2021).

Table 6.2: Level of maturity of BIM education between universities

Criteria	**Level 0 (Non-existent)**	**Level 1 (Initial)**	**Level 2 (Managed)**	**Level 3 (Integrated)**	**Level 4 (Optimizing)**
BIM in university vision	93% 211	7% 16	0%	0%	0%
Software	52% 118	48% 109	0%	0%	0%
Hardware	68% 154	32% 73	0%	0%	0%
Facilities	76% 173	24% 54	0%	0%	0%
Curriculum development	92% 209	8% 18	0%	0%	0%
Staff development	93% 211	7% 16	0%	0%	0%
Teaching and learning resource	95% 216	5% 11	0%	0%	0%

Table 6.3: BIM education challenges, according to participants in Survey B.

Challenges	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
Lack of awareness	48% 108	28% 63	13% 30	8% 19	3% 7
Insufficient funding source to train staff	19% 43	45% 102	19% 44	10% 23	7% 15
Lack of staff interested in teaching BIM	32% 72	44% 101	20% 45	4% 9	0% 0
Lack of qualified staff to teach BIM	44% 99	32% 73	15% 33	7% 15	3% 7
Lack of good computers and proper equipment	20% 45	56% 128	16% 36	8% 18	0% 0
Rapidly evolving technology	8% 18	16% 36	51% 115	23% 53	2% 5
Limit access software for students	20% 45	48% 110	16% 36	16% 36	0% 0
Lack of academic and professional collaboration	15% 33	51% 115	20% 45	11% 24	4% 10
Lack of support from the government	28% 63	33% 74	28% 63	8% 18	4% 9
Reluctance for changing curriculum	37% 83	29% 66	26% 60	8% 18	0% 0
No accreditation standards	10% 22	15% 33	18% 41	34% 78	23% 53
Longer time needed to restructure curricula	16% 36	33% 74	20% 45	16% 36	16% 36
Longer time needed to learn BIM software	10% 23	12% 27	20% 45	32% 73	25% 57
No room available for a new course	18% 41	24% 54	37% 83	12% 27	10% 22
Lack of students interested in learning BIM	7% 17	14% 31	18% 41	28% 63	33% 75
Using BIM tool in design can harm creative thinking	4% 9	8% 18	12% 27	29% 65	48% 108
Lack of BIM teaching methodology	28% 63	28% 63	28% 63	28% 63	28% 63
Lack of available resources	14% 31	24% 54	37% 83	22% 50	4% 9

BIM education challenges (Q23). **Table 6.3** shows the obstacles educators and institutions face when integrating BIM into their curricula. The responses highlight several key challenges:

- Lack of awareness: The majority of respondents (76% between strongly agree and somewhat agree) perceive lack of awareness as the most significant challenge. This highlights the need for greater awareness campaigns and educational efforts to inform educators and students about the importance and benefits of BIM in the AECO sectors and architectural education.
- Reluctance to change curriculum: a significant proportion of respondents (66% strongly agree) view reluctance to change curriculum as a major challenge. This resistance to altering existing academic structures may hinder the integration of BIM education, emphasizing the need for strategies to overcome resistance and facilitate curriculum adaptation.
- Lack of suitable computers and equipment: Over half of the respondents (56% somewhat agree) identify the lack of suitable computers and proper equipment as a notable challenge. This highlights the practical infrastructure limitations that academic institutions may face when implementing BIM education. Addressing this challenge may require investments in technology and facilities.
- Lack of qualified staff: 44% of respondents consider the lack of qualified staff to be a significant hurdle. Having educators with the necessary expertise in BIM is crucial for effective instruction. To meet this challenge, developing faculty competencies and qualifications in BIM-related fields is essential.
- Lack of academic and professional collaboration: A substantial 51% of respondents somewhat agree that there is a lack of collaboration between academia and the professional industry in the context of BIM education. This disconnects between academic institutions and real-world BIM practices can hinder the effectiveness of educational programs.

The survey results emphasize that while there is a clear recognition of the importance of BIM education, numerous challenges exist in integrating BIM into architectural programmes. This finding is consistent with previous research on BIM education challenges (Belayutham et al., 2018; Boton et al., 2018; Chen et al., 2020; Shibani et al., 2020; Casasayas et al., 2021). Addressing these challenges requires a multi-dimensional approach that involves raising awareness, fostering a willingness to adapt, investment in technology infrastructure, professional development, academic and professional collaboration, and staying abreast of technological developments (Casasayas et al., 2021). Overcoming these obstacles is essential to prepare students for the demands of the AECO sectors and ensure the successful adoption of BIM in education.

6.7 Findings from Survey B

The Survey B aimed at gathering data on BIM integration in undergraduate architectural education in Libya, provide valuable insights from the perspectives of the respondents.

This mixed-methods survey, which included both closed-ended and open-ended questions, enabled a comprehensive assessment of educators' experiences, awareness, utilization, training needs, and teaching methods related to BIM. Here is an expanded summary of the key findings.

- Architectural education in Libya lacks a standardized BIM education curriculum and well-defined prerequisites for the BIM education integration process. There is neither a strategy for adoption nor a plan for implementation in most institutions' various areas of architectural curricula.
- Autodesk AutoCAD tools are the most popular software taught in the architectural programme. This shows that most architectural programmes were still teaching students how to produce drawings using the traditional way of 2D drafting. Exposure to modern teaching software is necessary for the effective implementation of emerging technologies by teachers; for instance, teachers should be trained on the use of Autodesk Revit rather than traditional 2D drafting and 3D modelling, as this will encourage the acceptance of BIM as an emerging architectural tool.
- Awareness regarding BIM among academics is still low. Most of the respondents are mildly or moderately aware of the existence of BIM, so there is a need for a greater awareness campaign among educators.
- Regarding BIM skill acquisition, educators should be provided opportunities to further their skills through training and workshops. The provision of incentives will encourage teachers to sharpen their skills through enrolling in training programmes and attending seminars and workshops rather than self-sponsoring.
- Universities should endeavour to incorporate the teaching of BIM in their curriculum to ensure that their students are well-taught and employable upon graduation. Most respondents believe BIM is not well focused in the existing academic curriculum in most universities.
- Regarding the experience of teachers with BIM, qualified and experienced teachers are needed to drive the concept of BIM rather than relying on conventional 2D and 3D modelling tools. BIM should be taught as an integrated course with cross-disciplines rather than fragmented.
- Respondents believe that BIM should be an integral part of architectural courses. In addition, most of the participants are willing to have a BIM course in their departments. It was suggested that BIM should be introduced in the first academic year, allowing students to practice through their studies and graduate with a professional level of proficiency. Collaboration and integration are keys to effective BIM deployment, where it is not restricted to a single course but used to all design-related modules. This seeks to replicate the educational field's working atmosphere.

- On the relevance of BIM, most respondents believe that BIM is an important tool in architecture and should be considered a relevant aspect of architectural education that should form part of its curriculum.
- There is a strong influence of government and professional bodies on the delivery of BIM education. Most of the respondents believe that government and professional bodies have moderate to extreme influence on BIM teaching in schools.
- BIM education should be the government's and academia's responsibility because both must contribute significantly to see the progress of BIM education.
- Necessary adjustments should be made to the existing academic curriculum to accommodate BIM education.
- Universities should seek assistance when necessary to ensure the effective introduction of BIM education in the sector; this will require adequate support and guidance from both government and private bodies. This help could be in the form of developing a good programme or assisting professionals in setting up workshops and seminars since BIM is relatively new.
- Students should be exposed to BIM education in the early years of their study to gradually enhance their learning and improve their theoretical points of view from the start.
- The existing curriculum in most universities should be restructured to integrate BIM with the existing modules.
- Most respondents believe universities are not yet ready to integrate BIM into their programmes due to a lack of resources. This is the major reason for the lack of awareness of BIM among most of the interviewed participants in this study. Most of the universities in the study area still lack the necessary software, hardware, facilities, staff, and learning resources to incorporate BIM.
- The major challenge facing BIM education in Libya, as per the respondents, is the lack of awareness and reluctance to make changes to the existing curriculum. Other things that hinder BIM education in Libya include a lack of qualified staff, a lack of systems or computers, and a lack of academic and professional collaboration.

6.8 Summary

This chapter analyses quantitative and qualitative data from a questionnaire-based survey (Survey B). The findings highlight the current status of BIM implementation and awareness in Libyan architectural education. Universities currently lack a standardized BIM curriculum and a strategy for adopting BIM software. Traditional 2D drafting tools remain prevalent, highlighting the need for educator training on BIM software. There is a need to improve BIM awareness among educators, emphasizing the importance of training programmes. In addition, universities have a responsibility to integrate BIM by adapting their curriculum and ensuring qualified instructors. Interdisciplinary collaboration is recommended for a more holistic approach compared to fragmented BIM courses.

The professionals practice recognises BIM as a crucial tool, and the influence of government and professional bodies significantly impacts its implementation in schools. However, several challenges hinder BIM education in Libya, including limited resources (software, hardware, staff), resistance to curriculum changes, and a lack of qualified staff. To address these challenges, universities need support from the government and private sector. This support could involve developing BIM programmes, assisting with workshops, and providing guidance for effective BIM education implementation.

Finally, the chapter recommends introducing BIM in the early years of architectural studies. This allows for gradual skill development and strengthens students' theoretical foundation in BIM. While universities are not yet fully prepared to integrate BIM due to resource limitations, a comprehensive approach involving curriculum development, educator training, industry collaboration, and government support is crucial for ensuring Libyan graduates possess the necessary BIM skills for success in the modern architectural field.

Chapter 7: Development of BIMEXAE Framework

This chapter describes the development of the BIMEXAE framework for BIM competence-oriented architectural education in Libya, which corresponds to Objective 3 of this research. This chapter can be grouped into three sections. The first section provides notes and guidance from previous chapters about BIM integration and challenges in architectural education. The second section discusses the framework dimensions to help educators develop a proper framework based on the current status of BIM education in Libyan architectural education. The third section presented the framework and described its content in in-depth detail.

7.1 Notes Extracted from Previous Chapters

This section aims to provide notes extracted from previous chapters related to BIM integration with architectural education. This study reveals that research and reports about BIM integration in the engineering curriculum are currently available, mainly about the architectural programme and curriculum. For example, the following studies have discussed a broad range of academic initiatives to integrate BIM into architectural education, with the following emphases:

- Teaching strategies (Clevenger et al., 2010; Liu et al., 2021; Mahran et al., 2022),
- Methods, teaching and learning materials (Solnosky and Parfitt, 2015; Ozcan-Deniz, 2016; Shelbourn et al., 2017; Olugboyega and Windapo, 2019).
- Curriculum design and planning (Abdirad and Dossick, 2016; Coates et al., 2018)
- Learning outcomes (Coates et al., 2018; Liu et al.,2021).
- Students' perceptions and requirements (Zou et al., 2019; Isanović and Çolakoğlu, 2020).

Despite initiatives to introduce BIM into architectural education, a general strategic plan has been lacking for its adoption at architectural education institutions (Maharika et al., 2020; Böes et al., 2021). BIM utilisation has undeniably been a crucial development in contemporary architectural and engineering, and so its adoption in higher education is critical. There is a need for greater collaboration between government authorities, academics, and professionals' practices to discuss current and future trends in incorporating BIM within the architectural education and AECO sectors. Such a collaboration would clarify professionals' practice requirements to academic communities, as Jin et al. (2019) recommended, and ensure continual updating of BIM education to bridge the gap between educational goals and the AECO sector's needs (Maharika et al., 2020).

This overview illustrates the variety of topics that BIM-related frameworks may address. This initiated a conversation regarding the need for a framework and the factors that must be addressed to create a framework enabling BIM deployment in Libya. The following sub-sections comprehensively review the status of BIM integration with architectural education in Libya.

7.1.1 BIM Integration in Architectural Education

The integration of BIM into architectural education is essential for preparing future architects for the evolving demands of digital technologies in AECO sectors. Most Libyan architectural educators and AECO professionals recognise the importance of BIM education to architectural students. However, the finding of Survey B shows that there is a significant gap in the adoption of BIM as a teaching component within academic institutions in the context of architectural education and related disciplines in Libya. In addition, this finding highlights the need for academic institutions to embrace BIM education in architectural programmes and curricula. These perceptions are consistent with previous research in the domain of BIM integration within architectural education. Studies by Ghosh et al. (2013), Silverio et al. (2016), and Casasayas et al. (2021) have emphasised the importance of incorporating BIM into architectural curricula, as it aligns with industry needs and prepares students for the demands of the modern digital AECO sectors.

One of the key benefits of BIM integration is to equip architectural students with essential practical digital skills that are in high demand in the job market. Graduates with BIM proficiency are more competitive and can expect to find a good chance to work in the AECO sectors (Budayan and Arayici, 2021). In addition, BIM integration also fosters innovation and collaboration among students. BIM also enables students to learn more interactively about architectural concepts, enhance their problem-solving skills, and collaborate effectively with multidisciplinary teams, skills essential in contemporary architectural practice (Damek et al., 2022).

To achieve successful BIM integration, academic institutions must invest in BIM software and hardware, offer specialised BIM courses or integrate BIM concepts into existing curricula, and provide training for faculty members (Badrinath, Chang and Hsieh, 2016). Establishing partnerships with industry stakeholders can also facilitate real-world exposure and application of BIM principles, enriching the educational experience (Silverio et al., 2016; Casasayas et al., 2021).

7.1.2 BIM Awareness, Importance, and Teaching

BIM has transformed the architectural and construction sectors, promising improved collaboration, data-driven decision-making, and sustainability in design and construction projects. However, a concerning BIM awareness gap among Libya architectural educators has emerged. A substantial portion (33%) of architectural educators demonstrate only moderate awareness of BIM, indicating an educational deficit that requires immediate attention.

Another significant concern is the limited adoption of BIM as a teaching component. Only a small percentage (14%) of educators incorporate BIM into their curriculum, highlighting the urgent need for curriculum development and faculty training. Integrating BIM into architectural education is crucial to equip students with the skills and competencies required for modern architectural practice (Coates, 2018; Hossain and Zaman, 2022). Architects are expected to be proficient in BIM tools to remain competitive and effectively address the industry's developing challenges.

Despite these challenges, it is encouraging to note that most respondents (58%) recognise the importance of BIM within architectural education. They acknowledge its integral role in contemporary architectural practice and emphasise the need for collaborative efforts between government bodies, professional organisations, and educational institutions to promote BIM education. These collaborative initiatives can bridge the existing educational gaps and ensure that architectural graduates are well-prepared to meet the industry's demands and contribute to advancing architectural practice in Libya.

7.1.3 BIM Challenges and Universities' Readiness to Teach BIM

The readiness of universities in Libya to teach BIM is a complex issue, influenced by various factors, including resources, faculty expertise, curriculum development, and collaboration with industry partners. Survey B results reveal that most (78%) of respondents believe that their respective universities are not adequately prepared to incorporate BIM into their educational programmes. This suggests a widespread perception of unpreparedness among academic institutions in Libya. In addition, BIM education faces several significant challenges, as revealed in Survey B:

- Lack of awareness: A predominant challenge is the lack of BIM awareness among educators. Many educators do not fully understand how BIM can transform the AECO sectors. To mitigate this, comprehensive awareness campaigns and educational efforts should be initiated to educate educators about the profound impact of BIM in the AECO sectors.

- Reluctance to change: Another significant obstacle is the resistance to altering existing curricula. Traditional academic structures can resist change (Shibani et al., 2020; Elias, 2022), making it challenging to integrate BIM education. Strategies must be devised to overcome this resistance and facilitate curriculum adaptation, ensuring that BIM concepts are seamlessly integrated into architectural programs.
- Lack of suitable resources: Practical infrastructure limitations, including the absence of suitable computers and equipment, pose a substantial challenge. Implementing BIM education often requires significant investments in technology and facilities (Maina, 2018; Damek et al., 2022). Universities must allocate resources to provide students access to the necessary BIM tools, ensuring a conducive learning environment.
- Lack of qualified staff: About 44% of respondents identify the lack of skilled staff as a significant hurdle. Educators with expertise in BIM are essential for effective teaching (Puolitaival and Forsythe, 2016). Developing faculty competencies and qualifications in BIM-related fields is imperative to address this challenge, ensuring that students receive high-quality BIM education.
- Lack of academic and professional collaboration: A notable challenge is the lack of collaboration between academia and professionals in the context of BIM education (Damek et al., 2022), with 51% of respondents acknowledging this issue. This disconnects between academic institutions and real-world BIM practices can hinder the effectiveness of educational programs. Encouraging collaboration between universities and industry stakeholders is vital to bridging this gap, allowing students to work on practical BIM projects and gain exposure to industry practices.

Addressing the challenges highlighted in this section is essential to ensure that universities in Libya are well-positioned to deliver effective BIM education. By raising awareness of BIM, adapting curricula, investing in resources, developing faculty expertise, and fostering collaboration with the industry, academic institutions can empower graduates to play a vital role in the BIM-driven transformation of the AECO sectors in Libya.

7.1.4 Professionals Expectations Regarding BIM Education

BIM has revolutionised architectural practice by transforming how architects, engineers, and construction professionals collaborate and implement building projects (Scott, 2016; Budayan and Arayici, 2021; Çapkın, 2022). As BIM gains importance, architectural professionals increasingly look to academia to prepare graduates for the evolving demands of the field.

Survey A results reveal that a large majority (86%) of architectural professionals believe that BIM education is essential for architectural students. This consensus underscores the urgency for architectural schools to incorporate BIM into their coursework. Architectural professionals expect graduates to possess a well-rounded BIM skill set encompassing both practical skills and theoretical knowledge, with 59% of respondents expressing this viewpoint. In addition, 88% of professionals strongly agree for a structured curriculum design and development approach in BIM education.

These expectations highlight the pivotal role of BIM education in preparing graduates for the dynamic demands of architectural practice. The incorporation of BIM into architectural curricula, combined with practical training and a focus on professional competence and development, is essential to meet these expectations (Adamu and Thorpe, 2016). Meeting the professional expectations of BIM education requires a concerted effort from academia and industry (Çapkın, 2022). By collaborating and providing specialized training, academia can ensure that graduates are well-equipped to contribute to the BIM-driven transformation of the architectural profession.

7.2 The Need for a BIMEXAE Framework

BIM has become a cornerstone technology within the AECO sectors, driving efficiency and collaboration in professional practices. The growing global adoption of BIM underscores the necessity of embedding BIM skills and knowledge within architectural education. As the demand for proficient BIM practitioners rises, educational institutions bear the responsibility of integrating this technology into their curricula to prepare students for the evolving demands of the industry. Integrating BIM into architectural education presents a multifaceted challenge, particularly in balancing the new digital skills with traditional architectural principles. This integration requires a strategic and systematic approach to curriculum design, ensuring that students develop robust BIM skills progressively throughout their education.

In developing countries, such as Libya, the challenges are more pronounced due to limited BIM awareness and adoption within academia, as well as insufficient incentives and resources for implementation. Government support, while crucial, is not enough to bridge these gaps. Therefore, a specific educational framework is needed to guide BIM integration in Libyan architectural education.

7.2.1 Challenges of Existing BIM Education Frameworks

A review of existing academic initiatives for BIM education frameworks reveals ongoing challenges preventing some universities from integrating BIM into their curricula, despite established frameworks in developed nations like the UK and Australia. For instance, the BIM Academic Forum (2013) in the UK and the IMAC Framework developed by MacDonald (2013) in Australia have attempted to address BIM education. However, several issues persist:

- Lack of comprehensiveness: Many frameworks do not offer a comprehensive solution for BIM integration, limiting their effectiveness in diverse educational contexts.
- Infrequent updates: Existing frameworks often fail to stay updated with the rapid evolution of BIM technology, leading to outdated educational practices.
- Limited scope: Frameworks designed for specific countries or user groups may not be adaptable to different educational systems, such as those in developing countries like Libya.

Furthermore, these frameworks have not been thoroughly evaluated, and there is a lack of publications detailing their application in architectural programmes or alignment with undergraduate requirements in Libya. Survey B indicated that 78% of respondents require assistance in adjusting their programmes to adopt BIM, underscoring the need for a technical solution namely, the development of a theoretical framework that addresses institutional integration issues to facilitate BIM incorporation into architectural education at the undergraduate level in Libyan universities.

7.2.2 Unique Aspects of the BIMEXAE Framework

This research proposes a BIMEXAE framework specifically designed to address the challenges and constraints of Libyan undergraduate architectural education. The primary differentiators of this framework from existing ones are as follows:

- Context-specific adaptation: BIMEXAE recognizes the unique challenges faced by Libyan universities, such as limited access to hardware and software resources, and a construction industry focused on local materials and techniques. The framework provides alternative learning methods and project examples that don't require expensive software, ensuring its applicability in resource-constrained environments.
- Flexibility and adaptability: BIMEXAE is designed to be adaptable to the specific needs and resources of each institution. It provides a modular structure with core

components that can be altered to fit different programme structures, faculty expertise, and student skill levels. For example, universities with limited access to BIM software can focus on foundational BIM concepts and workflows using open-source tools, while those with more resources can integrate advanced BIM modelling exercises.

- Progressive learning model: BIMEXAE supports the progressive learning approach, enabling students to gradually build their BIM skills throughout their curriculum. In the first year, students might be introduced to basic BIM concepts and terminology. As they progress through the programme, they can engage in more complex modelling exercises and BIM-enabled design projects. This aligns with their evolving knowledge base and prepares them for real-world BIM applications.
- Standardization and structure: BIMEXAE aims to provide a standardized approach for integrating BIM into curricula, while still allowing for flexibility. It defines core learning outcomes to ensure graduates possess a foundational understanding of BIM, regardless of the specific university they attend. This consistency is crucial for ensuring graduates are prepared for national accreditation requirements and industry expectations.
- Detailed curriculum development guidance: The framework offers practical guidance on incorporating BIM content into existing courses. It includes suggested course structures, content outlines, and recommended teaching methods appropriate for different learning styles. This empowers faculty members, even those with limited BIM experience, to effectively deliver BIM instruction.
- Faculty development initiatives: BIMEXAE acknowledges the importance of faculty expertise in successful BIM integration. The framework outlines training programmes and resources to enhance educators' BIM knowledge and pedagogical skills. This ensures they are confident and prepared to deliver engaging and effective BIM education.
- Infrastructure recommendations: BIMEXAE provides recommendations for the technological infrastructure required for BIM education. It guides universities in making informed investments in hardware, software, and facilities, considering factors like budget constraints.
- Academia-industry collaboration: BIMEXAE emphasizes the importance of partnerships with industry stakeholders. The framework encourages collaborations that provide students with real-world project experiences and access to industry expertise. This exposure allows students to see the practical applications of BIM and prepares them for a smooth transition into the workforce.
- Readiness assessments: The framework advocates for readiness assessments to help institutions evaluate their current state of BIM integration and identify areas for improvement. This self-assessment process allows universities to develop a

roadmap for successful BIM implementation, considering factors like faculty expertise, curriculum alignment, and infrastructure needs.

7.3 Dimensions of the BIMEXAE Framework

The development of a BIM education framework is an important step towards advancing the integration of BIM into architectural education. This framework can provide a structured approach to teaching BIM and help ensure students receive a comprehensive and well-rounded education in this emerging technology. In addition, many connected terminologies, and ideas, such as adoption, implementation, dissemination, integration, and readiness, are frequently utilised interchangeably in the perspective of BIM, as seen by the debates around BIM adoption across education and the AECO sectors. Researchers also build detailed embracing roadmaps highlighting the importance of education in the policy formation process for adopting BIM. The primary objective of teaching and learning is to develop competencies, learning modules, educational frameworks, and awareness across all supply chain stakeholders, involving the education of instructors (Kassem and Succar, 2017).

A literature review of academic publications on positive practices of BIM in education and studies relevant to the identified challenges were conducted, and the summary of this review is presented in **Annex 7**. The framework was grouped into three dimensions, and six main criteria were identified from the literature review and supported by survey outcomes (See **Table 7.1)**. These criteria are specified and adopted in developing a BIM-integrated education framework. Although **Table 7.1** can be used more widely as a generic guideline across individual subject fields in the built environment discipline to establish a proper BIM educational framework, this research focuses on BIM adoption for architectural education in Libya. The literature review and questionnaire-based survey results identified the criteria as significant pathways to BIM adoption in architectural education. Details about the framework dimensions and criteria and their uses in this study are described in greater detail in the following sections.

Table 7.1: Dimensions and criteria for the BIM education framework

Dimensions	Main criteria
1. Professional development	1.1. Professional competence and development
	1.2. Academic and professional collaborations
2. Education product	2.1. Convergence of educational strategy, vision, and operation
	2.2. Inclusive curriculum design and development
3. Education process	3.1. Educational infrastructure and resources management
	3.2. Education process enhancement

7.4 Dimension 1: Professional Development

This dimension focuses on developing the professional skills and knowledge of individuals that required to lead the adoption of BIM in education. It consists of two main criteria including:

- Professional competence and development and,
- Academic and professional collaborations.

Details are described below.

7.4.1 Professional Competence and Development

The educational role of trained personnel and lecturers is vital for successfully implementing BIM in academic practices. Even if teachers are experts in their fields, they may lack the requisite expertise, practical skill, and knowledge of BIM models related to their disciplines (Isanović and Çolakoğlu, 2020). Incorporating BIM technology into architectural education practice is a relatively new educational aim; consequently, teachers are unfamiliar with the necessary strategies, which can pose difficulties for educators. The incorporation of BIM into architectural education practices could potentially constrain teachers, as they may be required to evaluate their position on digital technology when supporting BIM learning tools. As a result, institutions should ensure that their lecturers receive appropriate continuing professional development in the advanced digital technology used in the construction sector, such as BIM tools (Puolitaival and Forsythe, 2016; Mihindu and Farzad, 2021). One-time seminars and workshops are insufficient to assist teachers in adjusting new BIM courses in their learning and teaching programs.

Motivation is critical to lecturers choosing to adopt BIM in their learning styles, methods, and techniques, as it provides an internal driving force (Underwood et al., 2015). Without motivated lecturers, BIM initiatives in architectural education will probably fail. Lecturers must also be convinced about the reasons why BIM is essential for them to support professional development. Lecturers tend to be most concerned about what is best for their students; thus, they must appreciate how BIM can enrich their teaching and learning through exposure to new opportunities. This entails stressing the differences to lecturers between incorporating BIM technologies as a delivery mechanism and integrating them into CAD courses.

Aside from understanding why BIM education is valuable for architecture students, teachers need to be familiarised with the management and technical skills that can be acquired from participating in BIM workshops (Woldesenbet et al., 2017; Budayan and Arayici, 2021). Evaluations conducted before the start of the professional development programme can assist trainers in identifying distinct areas for advancement and in providing a suitable training programme. University trainers should revisit workshop themes regularly to ensure that they continue to meet the diverse self-development needs of teachers. Workshops should be more concerned with the implementation approach than developing a more profound mastery of the logic of teaching education. Pedagogical support for the unit's BIM design courses must be provided from conception to implementation and review. Such guidance would assist in applying new BIM teaching strategies and tools in non-technical capacity development to increase lecturers' comprehension of the traditional shifts in learning and new teaching methods associated with the incorporation of BIM in architectural education.

Teachers equipped with BIM experience could also be employed to assist their colleagues by teaching team sessions at their institution. A combination of teaching with peer training may help limit the reluctance teachers and/or students might encounter while attempting to incorporate BIM within their courses. Professional development must be consistent, and tutors' experiences should be continuously evaluated, improved and developed to ensure educators remain engaged in learning to enhance the quality of teaching in architectural education. This should be a fundamental condition of professional development culture (Mare, 2021). To reconcile the tradition of abstraction with synthetic simulation, educators must look into and develop innovative methods based on the multidimensionality of BIM and skill-building, which includes conveying BIM design studio challenges. BIM may present a new challenge for tutors wishing to influence students' level of skills and knowledge. Current barriers include the lack of research and reference materials, model development not following a set order, failure to detect errors and limited database component choices.

Also, as noted by educators, using a BIM model is preferred by students and lecturers in CAD sessions compared to workshops and seminars (Jin et al., 2020; Damek et al., 2022), especially for help functions, user-friendliness, and the ability to detect modelling mistakes. From a student perspective, BIM enriches their knowledge and helps them better understand the building system, allowing them to create complex designs (Shelbourn et al., 2017). Further research in sustainability in building technology and infrastructure is required to develop innovative pedagogical methods to bridge the gap between professional needs and students' abilities and effectively incorporate BIM in architectural education.

7.4.2 Academic and Professional Collaborations

The development, implementation, and adoption of change are challenging for a team. No higher education institution is likely to succeed fully in transition without assistance. Institutions can make collaborative and symbiotic partnerships that influence each team's experience and expertise. To ensure effective BIM incorporation within architectural education, two types of educational collaborations might drive BIM education, including:

- Academic-to-academic collaborations, and
- Academic-to-professional collaborations.

Details are described below.

7.4.2.1 Academic-to-Academic Collaborations

To lead digital technology transformation in the education sector, creating effective collaboration between academies is essential to enhance educational quality. Regarding the adoption of new technology, initial collaborations can involve the IT team at the university. The IT team can assist in diagnosing the current status of architectural labs in terms of the necessary hardware and software in the first stage of adoption.

Institutions should encourage inter-department collaboration, which entails dividing resources and developing consistent practices across architectural departments. Such collaboration could reduce the repetition and duplication of teaching resources, reducing staff workload. A positive example of academic partnerships in BIM education can be found in the UK, where a strategic roadmap for BIM incorporation into the curriculum for higher education certification has been established by the BIM Academic Forum (BAF), comprising leading academics from the UK and Irish universities (BAF, 2013). The BAF has defined key BIM learning outcomes to be acquired at undergraduate and graduate levels, which presents a clear objective for BIM education in the UK.

Globalization has facilitated the union of higher education institutions across international borders and the coordination of efforts to achieve common goals and objectives in the areas of technology sharing, case studies, research, resources, and reports. Some institutions have collaborated and compared with others, demonstrating institutional collaboration's significance in decreasing effort, sharing rewards, and improving processes. Such collaboration would be a step towards preventing errors and would assist other institutions in integrating these approaches and avoiding duplication of effort (Besné et al., 2021). Thus, sharing practices for delivering BIM education could involve international institutional collaboration between universities. The collaboration among all AECO education disciplines is vital for developing a valid and reliable architectural BIM education programme.

7.4.2.2 Academic-to-Professional Collaborations

Close collaboration between professionals and educators is vital to the two-way exchange between learning and reality. Experienced professionals with teaching qualifications are essential for motivating students and fostering the development of their talents concerning AECO sector requirements (Abdelhai, 2022). The primary goal of academic-to-professional collaborations is to establish formal relationships and connections between academics and industry professionals who are interested in integrating and improving cutting-edge approaches to BIM education. Developing partnerships with professionals can help educators generate substantial course content that recognises the main BIM competencies needed in practice (Silverio et al., 2016). Professionals can also offer practical training for staff and students to improve their knowledge of BIM tools. Academic-industrial collaborations are also a key component when bringing guest and assistant lecturers to teach BIM exercises and assisting students during tutorials on how to apply BIM technologies (Ghosh et al., 2013; Casasayas et al., 2021). The collaboration between universities and industry could help limit the gap between educational outcomes and industry requirements (Chen et al., 2020).

Universities might also collaborate and form relationships with private sector firms. Such relationships enable institutions to examine various educational technologies to develop future BIM practices with the involvement of industry professionals. The public and private sectors, which are invested in the pedagogical advancement of higher education, can provide financial and professional support. In general, collaborations between universities and AECO firms can benefit all parties as research conducted by universities drives progress (Boton et al., 2018). Excellent architectural education and practice require a mutually integrated collaborative environment that benefits the various stakeholders, including professional associations, architectural schools, and firms (Zaed and Chen, 2021). These stakeholders can collaborate to develop national architectural and BIM education standards.

7.5 Dimension 2: Education Product

This dimension concentrates on the design and content of the BIM educational programme itself, including:

- Convergence of educational strategy, vision, and operations, and
- Inclusive curriculum design and development.

Details are described below.

7.5.1 Convergence of Educational Strategy, Vision, and Operation

The US National Science Foundation defines convergence as the in-depth integration of information, techniques, and skills from various areas to build new and enlarged frameworks to solve scientific and social issues. Convergence in education can accelerate the development of further information that does not fit readily into the existing curriculum (Herr et al., 2019). Meanwhile, Becerik-Gerber et al. (2011) discovered that there is no obvious pattern among AECO programmes in terms of how and when BIM is introduced into the AECO curriculum, and more recent research suggests a convergence in terms of how and when to introduce BIM ideas. Convergence refers to a shift in how architecture is practiced, and architects are trained. Kocaturk and Kiviniemi (2013) suggest that this is a transformational process that necessitates a reconsideration of architectural education and practice. The following subsections explore how universities can move beyond traditional learning and achieve convergence by strategically aligning their overall educational vision with the goals of BIM education and developing a strategic plan for effective BIM implementation.

7.5.1.1 Aligning University Vision with BIM Education

The initial step when adopting BIM in architectural education is to include BIM in the vision and mission of the university. University vision is one of the essential elements of any strategic plan in education development. A university vision is an idealised descriptive depiction of a university's prospective future consequences, developed to align with a specific timeframe (Hinton, 2012). Although the university vision may not specify BIM, it provides a formula for policies and actions consistent with architectural education's growth. For example, an architectural university's future vision and strategy might include equipping students with quality education in new technology in the built environment (Damek et al., 2022). The university intends to adopt BIM to maximize students' future potential and increase their competitiveness and potential for employment. As a result, it is critical to have a vision around which to build a plan to integrate BIM into the curriculum (Adamu and Thorpe, 2016).

A specific vision needs to be implemented in the philosophy of the university wishing to adopt BIM in architectural education successfully; this vision should include both teaching and learning techniques in a collaborative context. As a strategic development goal, a BIM perspective can be established in universities to implement BIM in the curriculum. Educators might plan BIM actions through a consistent policy approach, recognising the internal obstacles and limits of the adoption of BIM into education (Casasayas et al., 2021). Additionally, institutions should place greater emphasis on budgeting for BIM implementation (Yusuf et al., 2017) and ensure programmes' sustainability (Maharika et al., 2020).

7.5.1.2 Developing a Strategic Plan for Effective BIM Implementation

Strategies incorporating relevant institutional structures can facilitate university development and transformation. The capacity of an organisation to translate strategic concepts into practical action is crucial to ensure the successful implementation of a strategic plan (Hinton, 2012; Lim et al., 2019). The university should ideally incorporate BIM implementation plans, policies, recommendations, and methods that are consistent with their objectives and future vision in order to inspire and motivate teachers to actively participate in the adoption of BIM education (NATSPEC, 2019). BIM education should be allowed to develop in accordance with techniques that foster faculty progress, as autonomy and flexibility are critical in supporting faculty innovation. Additionally, encouragement is vital since it is necessary to explain to teaching staff how what is valued in architectural education is changing and why. When teachers understand how BIM contributes to enhanced university outcomes and satisfies industry standards and how it may become an integral element of staff evaluation, it is more likely that BIM will be included in academic procedures.

Positive student evaluations are also necessary to improve the content of BIM courses. BIM teaching tactics are distinct from those previously used, such as in 2D CAD. Hence, BIM should be introduced to students gradually to ensure the best results and reinforce the ability to learn from mistakes (Boton et al., 2018). Constructing realistic higher education policies when introducing new curriculum elements requires understanding the student population and institutional values. Educators, administrators, and practitioners should recognize that the influence of these policies is cumulative and involves several years of sustained work.

The broader university aims may result in the formation of a new institutional implementation strategy for BIM education efforts in architectural education support. University designers and BIM advocates might be assigned to a department to facilitate the development of best practices in BIM education that are compatible with the disciplinary requirements of architecture and allied disciplines. (NATSPEC, 2019; Badrinath et al., 2016). Teachers should be aware of students' limited capacity to adapt to current learning methods and implement new learning and teaching strategies. Introducing a significant BIM component requires considerable effort, time, and input to achieve an effective BIM-integrated curriculum.

7.5.2 Inclusive Curriculum Development

Curricular development is a methodical process in which courses with specific subjects are planned and constructed. Any new curriculum should be effectively translatable into practice with suitable pedagogical methods included matched to users' learning needs (Heywood, 2010; Triki, 2016). A curriculum gives insight into what to learn, a reason to learn, and the modes of facilitating this learning. Inclusive curriculum design and development must consider various stakeholders, including governments, employers, training organizations, teachers, and students (Devlin and Samarawickrema, 2010). As stated by Tyler, higher education providers should formulate questions regarding an inclusive curriculum design. These questions include: What is the purpose of the curriculum? To meet the expected goal of the curriculum, what experience should the institution have? What is the most effective way of organizing the curriculum? In achieving the curriculum purpose, how can one best describe the results of learning? (Tyler, 2013).

There is continual growth in content knowledge, and new experiences evolve rapidly; hence, current curricula cannot rely exclusively on transmitting knowledge from teachers to students (Lim, Wang and Graham, 2019). Rather than acquiring practical knowledge, there should be a focus on curriculum orientation and design to build a platform for learners to apply what they have learned in their workplace. This knowledge results in enhanced twenty-first-century successes (Pellegrino, 2013) in the areas of expert analysis, creation, and analysis, as well as dealing with developing economies. Therefore, future AECO professionals must be able to work in a multidisciplinary team and use 21st-century advanced ICT technologies (Chan, 2014). BIM education offers the means to achieve this goal (Olugboyega and Windapo, 2019).

BIM education encompasses various subjects, and students have limited time to learn about BIM and other relevant university courses. Critical thinking is a vital component of twenty-first-century architectural education. Thus, architectural education should encourage higher-order thinking (Kararmaz and Ciravoğlu, 2017), which results in the development of both academic and professional skills and improved learning collaboration. Therefore, restructuring the architectural curriculum to incorporate BIM across disciplines is crucial. BIM is more than software; it's a new workflow and philosophy of collaboration. Integrating this complexity into existing curricula requires careful planning and adaptation.

The Periodic Table of BIM developed by NBS (2016) offers a helpful starting point for individuals and organizations looking to navigate the world of BIM effectively. This framework proposes an approach for incorporating BIM skills:

- Strategy: Define the strategic goals of BIM adoption in architectural education.
- Foundations: Develop a structured framework for progressively building BIM skills throughout the curriculum. This includes introducing BIM terminology, standards, and diverse software options to equip students with a solid understanding.
- Collaboration: Implement group projects, simulations, and real-world collaborations to enhance teamwork skills.
- Process: Offer an in-depth journey through the BIM process, covering team roles, tools, and technologies.
- People: Integrate role-playing, simulations, and communication workshops to develop essential soft skills.
- Technology: Expand hands-on training with diverse BIM software and project-based applications.
- Standards: Enhance understanding with comprehensive coverage of national and international BIM standards, their benefits, and implementation strategies.
- Enabling Tools: Provide dedicated training on BIM toolkits, classification systems, and authoring tools for effective content creation, analysis, and collaboration.
- Resources: Equip students with access to BIM software, online resources, professional organization memberships, and social media communities for continuous learning and networking.

With the implementation of the Periodic Table of BIM as a guide, architectural education can effectively equip future professionals with the skills and knowledge needed to thrive in the BIM-driven AECO sector. In addition, there is a need to develop an inclusive curriculum for BIM in architectural education across three stages: curriculum design, curriculum development, and curriculum implementation.

7.5.2.1 Curriculum Design

Curriculum design is the roadmap for successful learning. When crafting a BIM curriculum, it is crucial to define the skills and knowledge students need to work in the AECO sectors (Coates et al., 2018; Lee et al., 2019). This process involves:

- Industry insights: Analyse case studies, best practices, and current industry standards to understand AECO sector trends in digital technology.
- Learning outcomes: Establish clear, measurable, and achievable learning objectives that meet both student and industry needs.

- Target audience: Identify the target audience to understand their background knowledge, existing skills, and learning goals.
- Smart Goals: Develop specific, measurable, achievable, relevant, and time-bound curriculum goals aligned with the desired learning outcomes.

7.5.2.2 Curriculum Development

Curriculum development is the process of creating and refining the content and delivery methods of the curriculum. BIM is a rapidly evolving field, and educational institutions must stay up-to-date with the latest developments to ensure that their curriculum remains relevant and effective (Casasayas et al., 2021). The BIM curriculum should also incorporate various teaching methods, such as lectures, group discussions, case studies, and project-based learning (Taban et al., 2021). This enables students to develop theoretical knowledge and practical skills and prepares them for a career in the industry. The curriculum development can involve the following steps:

- Content selection: Choose appropriate curriculum content, including textbooks and software, that aligns with the BIM curriculum goals.
- Modular learning outcomes: Develop specific learning outcomes for each module or unit, drawing from the chosen content and overall curriculum goals.
- Detailed lesson plans: Create comprehensive lesson plans that guide the delivery of each module, ensuring a smooth progression towards the learning outcomes.
- Assessment strategies: Define the methods used to evaluate student performance and verify the achievement of learning outcomes.

7.5.2.3 Curriculum Implementation

Curriculum implementation is the process of bringing the BIM programme to life (Olowa et al., 2020; Besné et al., 2021). It involves delivering content, assessing student progress, and continuously refining the curriculum for maximum effectiveness. The curriculum implementation can involve the following steps:

- Faculty training: Train teachers on the curriculum content, learning outcomes, and assessment methods. This empowers them to deliver the programme effectively.
- Structured delivery: Present curriculum content in a clear and organised manner. This ensures students achieve the intended learning outcomes.
- Assessing progress: Use the defined assessment methods to evaluate student performance and gauge comprehension of the learning outcomes.
- Continuous improvement: Regularly assess the curriculum through student feedback, performance data, and industry input (Hossain and Bin Zaman, 2022).

This continuous feedback loop ensures the programme stays relevant and up to date with AECO practices.

7.6 Dimension 3: Education Process

This dimension deals with the methods and logistics of delivering BIM education, and its development needs to consider two essential criteria, including:

- The importance of educational infrastructure and resources, and
- How the education process can be enhanced.

Details are described below.

7.6.1 Educational Infrastructure and Resources Management

Integrating BIM into architectural education requires proper teaching and learning resources, facilities, and technological infrastructure.

7.6.1.1 Software, Hardware, and Facilities Infrastructure

Information, communication, and technology readiness in higher education institutions are essential aspects regarding BIM achievement despite ICT not influencing changes in higher education institutions (Lim et al., 2019). Setting up BIM requires diligent human resources management, physical infrastructure, and adequate financial resources to finance BIM education in higher education institutions (Chihib et al., 2019; Abdirad and Dossick, 2021). In addition, the institutions should carefully plan with software and hardware vendors to consistently achieve the needs of students and teaching staff. As usage and demand increase, scalability blueprints are necessary to enhance the infrastructure to teach BIM in a collaborative environment.

Sufficient information technology and hardware infrastructure, such as using computers to introduce BIM stand-alone courses, is essential for an institution wishing to start to introduce BIM (Maina, 2018; Maharika et al., 2020). Incorporating digital media in design requires addressing the polarity between digital and traditional media and cross-disciplinary combinations, media-rich environments, and multimodal development. Mature institutions will have adequate infrastructure to apply collaborative BIM teaching and learning such as BIM in a computer network and the financial resources to manage them (Yusuf et al., 2017). Research suggests that BIM has the potential to evolve into a comprehensive learning platform for teams distributed globally and to facilitate the development of empirical educational settings. Online learning platforms reportedly offer a positive learning experience for both teachers and students, especially during the Covid-

19 pandemic (Tsai et al., 2019; Boton, 2020). Infrastructure readiness requires multidisciplinary collaboration and technical depth in BIM learning to meet professional standards, specialized skills, and a continual emphasis on a practice-based environment. Choosing technological tools to fulfil functional needs and requirements and non-technical issues is essential in developing BIM incorporation and adoption stages, in which collaborative initiatives have an indispensable role. By integrating BIM with geographical information systems and infrastructure, mature institutions will be able to leverage their infrastructures and resources to apply BIM technology outside learning and teaching (for instance, outreach collaborations and services), industry, and campus facility management.

7.6.1.2 Teaching and Learning Resources

In many situations, teachers develop their teaching materials, equipment, and resources using online tools to instruct the students and increase their knowledge and capabilities. It is not common for many institutions to share resources among teaching staff or various courses. However, were they to do so, resources of little value could be recycled, perfected, and made more productive and valuable, possibly serving different disciplines. Archiving digital assets is a vital aspect of facilitating sharing and resource management. Different teaching methods should also be incorporated into BIM, such as tutorials and lectures to enhance student knowledge, seminars and workshops to train students on BIM non-technical skills and to show the practicability of theoretical studies, and online resources (Eadie et al., 2016; Maina, 2018). Explanations of BIM principles theoretically include BIM tools such as; audit, authoring, analysis, and prototypes of the building-specific resources needed, and BIM teaching and impacting reliable knowledge to learners (Puolitaival et al., 2015). Theoretical resources used in teaching and learning are available in articles, websites, and books that are easy to locate, and several different teaching and learning tools are available for educational purposes. However, actual BIM models are challenging to prepare and adapt to ensure high-quality educational value.

Key resources for BIM courses include construction, engineering, architecture, computer tools, geometric modelling, and digital data. 4D planning, automated bill of quantities, automated estimating packages, visualization and simulation, clash detection, and code checking should be used for BIM environments. These resources should also use IFC-compliant software. However, students should initially learn how to apply BIM tools that apply to their requirements, as each professional discipline has a specific set of BIM tools and principles (Hammi and Ouahrani, 2019). Hence, educators can identify BIM principles pertinent to their field, choose appropriate software for students to use, and apply tools available in educational versions. Effective computing management and infrastructure are essential, but a simple, smart board can be used as an effective tool to engage several BIM students in discussions simultaneously. BIM manuals can also be used to emphasize the need for skilful software and information content.

7.6.2 Education Process Enhancement

Improvements to the educational process may be enhanced and encouraged by publications, evaluations, and even students' perceptions. Thus, it is necessary to review and refine standard enhancements of the education process in architectural education to keep them up to date. University educators should carry out test control projects to determine possible and potential outcomes before large-scale implementations, learn from mistakes, and identify best practices for BIM courses (Boton et al., 2018). This vital stage might support architectural education, identify and address likely complications and assess the outcomes of the introduction of teachers and learners to a new dynamism before large-scale application.

Research and evaluation may include analysing students' perceptions of BIM practices and visualization to reveal valuable participation, collaboration, and BIM course results (Zou et al., 2019; Boshrabadi et al., 2021). This could also enhance teachers' ability to adopt BIM as a practical learning technique and encourage institutional leaders to promote BIM education through strategic initiatives. Moreover, it could assist institutions in making their BIM programmes efficient by recognizing practical implementation strategies. Some research assessments would also prove beneficial from a professional development viewpoint, offering each teaching personnel proof-based views to improve their BIM teaching methods.

In order to better comprehend suitable BIM teaching activities for teachers when applying BIM in their courses, research groups can incorporate case studies in their research at the institutional level. Through actual research, inspired teaching staff may document their practices and outcomes about BIM. Similar to professional development and policy, motivational plans that support and award academic practices connected to what BIM can provide should be implemented to strengthen the research-teaching relationship.

7.7 The Development of the BIMEXAE Framework

The integration of BIM in Libyan architectural education is still in its early stages, as most respondents indicated in Survey A and B. Therefore, there is a need to develop a comprehensive framework to facilitate the implementation of BIM in architectural education and practice. The framework needs to cover different aspects, including institutional integration issues and BIM curriculum content. The framework was developed through a systematic process that consisted of several steps. The first step was to determine the type of framework that would be most effective in addressing the challenges of integrating BIM into architectural education in Libya.

The field of Knowledge Management (KM) identifies three main types of frameworks: descriptive, prescriptive, and hybrid (Kassem et al., 2014). Descriptive frameworks focus on describing complex phenomena, while prescriptive frameworks provide methods for implementing them. Hybrid frameworks combine elements of both descriptive and prescriptive frameworks to provide both procedural steps and contextual information.

In the case of BIM integration into architectural education in Libya, the hybrid framework was chosen as the optimal strategy. This decision was based on the realisation that successful BIM implementation requires both actionable steps and methodologies and contextual insights and knowledge to guide stakeholders effectively. The chosen framework aimed to provide a roadmap for implementation and a thorough understanding of the underlying principles and the contextual relevance of BIM integration in Libyan architectural education.

The next step in the framework development process was based on the analyse existing literature reviews in the identified criteria based on the survey outcomes related to BIM education (See **Section 7.1** and **7.3** to **7.6**). This analysis was used to determine the strengths and weaknesses of different frameworks and to inform the development of the new framework.

The final step in the development of the BIMEXAE framework was to formulate the framework that covers all the requirements for the implementation of BIM in architectural education in Libya. This framework was divided into two parts:

1) A four-phase procedure for BIM programme development: This procedure establishes a strategic framework based on the defined evaluation criteria. It aims to support institutional planning efforts for integrating BIM within architectural education.
2) A four-year BIM-integrated curriculum: This curriculum guides the full implementation of a BIM-focused programme for undergraduate architectural education in Libya.

The development of BIMEXAE framework is a significant step forward in the advancement of BIM education in Libya. The framework provides a comprehensive and systematic approach to the implementation of BIM, and it is expected to play a major role in the transformation of architectural education in Libya. The following subsection discusses the framework implementation in more detail.

7.7.1 A Four-Phase Procedure for BIM Programme Development

The integration of BIM into architectural education programmes requires a systematic approach to ensure its effectiveness and relevance. This led to revisions of the initial framework developed in this study (Refer to **Annex 9**). The final framework for BIM integration within an architectural programme is outlined in the four-phase procedure illustrated in **Table 7.2**.

Table 7.2: A Four-Phase Procedure for BIM Programme Development

Phase	Stage	Description
Phase1: Programme Conceive and Diagnose	1.1 Programme Conceive	Defines BIM education purpose, goals, and university vision for BIM.
	1.2 Programme Diagnose	Conducts assessment of current curriculum, infrastructure, faculty skills, and industry partnership potential.
Phase 2: Programme Design and Development	2.1 Curriculum Design and Development	Develop a BIM curriculum integrating concepts, tools, and workflows, potentially including new courses
	2.2 Education Infrastructure Development	Invests in technology and resources based on current infrastructure
	2.3 Professional Development	Provides training for academic and non-academic staff to enhance BIM skills
	2.4 Educational Partnership	Formalizes partnerships with industry stakeholders for collaboration
Phase 3: Programme Intervention and Implementation	3.1 Curriculum intervention and Implementation	Implements BIM-integrated curriculum and monitors student progress
	3.2 Education Infrastructure Implementation	Implements technology upgrades: hardware, software installation, and licenses
	3.3 Professional Development Implementation	Offers ongoing professional development for faculty and staff
	3.4 Educational Partnership Implementation	Fosters strong collaboration with industry partners through projects, internships, and workshops
Phase 4: Programme Operation and Evaluation	4.1 Continuous Evaluation and Monitoring	Evaluate BIM programme effectiveness and gather stakeholder feedback
	4.2 Programme Enhancement and Innovation	Uses evaluation results to make informed adjustments and enhancements

This four-phase procedure draws inspiration from established engineering education frameworks such as CDIO (Conceive, Design, Implement, and Operate) and ESD (diagnostic stage, design and development stage, intervention and implementation stage, and evaluation stage). These frameworks provide a strong foundation for the iterative nature of BIM programme integration, as discussed in **Sections 2.6.1.1** and **2.6.1.2.**

Resources such as the AiC BIM Body of Knowledge and NBS Periodic Table of BIM provide a valuable knowledge base BIM (Refer to **Sections 2.6.1.4** and **2.6.1.5 Annex 6)**. During the design and development phase, these references can guide the selection of specific BIM elements and concepts for inclusion in the curriculum, ensuring a comprehensive and evolving BIM programme.

This dynamic approach ensures a developing BIM programme, preparing graduates for success in the AECO sector. The implementation of the four-phase procedure for BIM programme development is detailed below:

7.7.1.1 Phase 1: Programme Conceive and Diagnose

This initial phase focuses on establishing a foundation for BIM integration within architectural education. It involves conceiving and diagnosing the current architectural programme to integrate BIM education.

Stage 1.1: Programme Conceive

This stage marks the crucial first step in integrating BIM into the architectural programme. As the university recognizes the growing importance of BIM in the industry, it becomes crucial to define the specific goals and vision for BIM education. This introduction explores these key steps:

- Programme vision and goal setting: when the university's willingness to adopt BIM to the architectural programme. It is critical to define the specific objectives and outcomes to achieve through BIM integration with architectural programmes. It is important to consider how BIM will enhance architectural education and practice and the long-term goals for BIM implementation within the programme.
- University vision for BIM education: It is very important to establish a clear vision statement that outlines the role of BIM in the university's architectural education. This vision statement should be developed with input from key stakeholders, including faculty, administrators, and industry professionals. It is also important to ensure that the vision aligns with the university's overall strategic objectives. Although the university vision may not specify BIM, it provides a formula for policies and actions consistent with architectural education's growth. For example, an architectural department’s future vision and strategy might include equipping students with quality education in new technology in the built environment. The university intends to adopt BIM in order to maximize students' future potential and increase their competitiveness and potential for employment.

Stage 1.2: Programme Diagnose

Before implementing BIM, this phase involves a comprehensive assessment of the current state of the educational programme. This includes evaluating the existing curriculum, education infrastructure readiness, faculty and staff skill levels, and the potential for valuable education partnerships.

- Curriculum analyses: After defining the purpose of BIM education integration, the university needs to analyse the existing curriculum to identify the gaps and opportunities for BIM integration. It is important to consider where BIM-related topics can be incorporated into the curriculum and the readiness of faculty and resources for curriculum change. At this stage, it is very important to identify BIM competencies needed for architectural students.
- Education infrastructure assessment: Evaluate the university's ability to support BIM education technologically. This includes assessing software, hardware, and dedicated teaching spaces. It is important to identify any shortages in facilities, laboratories, or equipment that need improvement or development. It is also important to consider the accessibility of BIM tools for students and faculty. In Libya, it was noted that Libyan universities still lack the necessary software, hardware, facilities, staff, and learning resources to incorporate BIM. Therefore, there is a need to propose a plan for the current infrastructure based on the department's identified learning objectives and the purpose of teaching BIM.
- Professional competence evaluation: Assess the current skill levels of faculty and staff regarding BIM technologies and methodologies. It is important to identify areas where professional development and training are necessary. It is also important to develop a plan for bridging the competency gap in BIM-related skills.
- Explore potential educational partnership: Identify potential collaboration types needed to assist in the BIM implementation process. Therefore, it is crucial to create a formal relationship between academics and professionals at the diagnosing stage. The initial collaborations can involve the IT team at the university. The IT team can assist in diagnosing the current status of architectural labs in terms of the necessary hardware and software in the first stage of adoption. In addition, developing partnerships with professionals can help educators generate substantial course content that recognises the main BIM competencies needed in practice and the provision of practical training for teachers on BIM tools.

7.7.1.2 Phase 2: Programme Design and Development

In this phase, the framework for BIM integration begins to take shape. It entails designing a BIM programme and curriculum that aligns with industry standards, developing the necessary educational infrastructure, providing professional development, and establishing strong partnerships with industry stakeholders.

Stage 2.1: Curriculum Design and Development

This stage involves developing a detailed BIM curriculum that integrates BIM concepts, tools, and workflows into existing courses. New courses or modules may also need to be created to cover BIM-related topics. Educators need to give different considerations during the curriculum design process, such as course content and materials, assessment criteria, and evaluation methods. It is important to ensure that the curriculum aligns with industry standards and best practices of BIM implementation and developed frameworks such as NBS.

It is recommended that universities implement BIM gradually to achieve progressive integration and prevent significant failure. For example, alter the architectural curriculum first and then the rest of the fields.

Stage 2.2: Education Infrastructure Development

This stage involves investing in the necessary technology and resources to support BIM education based on the current education infrastructure of the university. At this stage, the institution needed to make agreements with a software and hardware developer to supply the university with suitable equipment to use BIM. Integrating BIM into architectural education requires the implementation of proper teaching and learning resources, software, hardware, and facilities infrastructure, which is essential in the programme development phase.

Stage 2.3: Professional Development

In Libya, it was noted that most of the educators and professionals involved in BIM education and training are self-learning. Although self-learning has made a good contribution in the country related to BIM implementation, there is a need to provide academic training for educators and professionals.

This stage involves providing training and professional development to academic and non-academic staff (Librarians, administration, and technicians) to enhance their BIM skills. Regarding academic staff, even if teachers are experts in their fields, they may lack the requisite expertise and practical knowledge of BIM models. This can be done with help from professionals interested in BIM curriculum development. In addition, there is a need to create a programme to encourage BIM learning in the facility, which can be done by arranging workshops for educators on the importance of BIM in digital construction and practice. It is also important to foster a culture of continuous learning within the institution. Motivation is key to the lecturer who decided to adopt BIM in their style, methods, and techniques.

Stage 2.4: Educational Partnership

This stage involves formalising partnerships with industry stakeholders for collaborative projects, guidance programmes, or knowledge sharing. The primary goal of academic-to-professional collaborations is to establish formal relationships and connections between academics and industry professionals who are interested in integrating and improving cutting-edge approaches to BIM education. In addition, professionals can assist educators in identifying the main BIM competencies required in practice. It is also important to create mechanisms for feedback and evaluation of partnership effectiveness.

At this stage, universities might also collaborate and form relationships with private-sector firms. Such relationships enable higher education institutions to examine various educational technologies to develop future BIM practices with the involvement of industry professionals. The public and private sectors, which are invested in the pedagogical advancement of higher education, can provide financial and professional support.

7.7.1.3 Phase 3: Programme Intervention and Implementation

This phase involves implementing the BIM-integrated curriculum, ensuring that technology supports the educational goals, offering ongoing professional development, and fostering significant collaborations with industry partners.

Stage 3.1: Curriculum Intervention and Implementation

This stage involves rolling out the BIM-integrated curriculum as planned. It is important to ensure that faculty members are equipped to teach BIM-related courses effectively. It is also important to monitor student progress and engagement with BIM materials.

BIM is recommended to intervene and implement gradually to achieve progressive integration and prevent a major failure. This integration can be achieved through three strategies: (1) modular strategy, (2) progression strategy, and (3) integration strategy. In modular strategy, BIM can be introduced with the program as a standalone module. This strategy aims to introduce BIM to students and train students on the main BIM tools, which offers a strong starting point for universities to raise awareness of BIM. A progression strategy can be used to integrate BIM with the various curriculum years. The benefit of this approach is to gradually incorporate BIM into a curriculum and ensure that students take on the underlying concepts to easily integrate the theory with technology. Typically, the integration approach follows the previous two and integrates complementary technology components into the university modules. Aspects of the BIM method are incorporated into the syllabus across many modules, such as design studio. Then, BIM can be used as an axis for the integration of the university programme. It offers an attractive way of making university integration of BIM education easier.

Stage 3.2: Education Infrastructure Implementation

This stage involves implementing necessary technology upgrades and improvements. These include hardware, installing the main BIM software, and providing licenses for staff and students. Sufficient information technology and hardware infrastructure, such as using computers to introduce BIM standalone courses, is essential for an institution wishing to introduce BIM. This also needs to provide suitable spaces for teaching and learning BIM. It is important to ensure students can access BIM software and tools. It is also important to maintain and support BIM labs or facilities.

Stage 3.3: Professional Development Implementation

This stage involves continuing to offer professional development for faculty and staff. The institution and educators need to understand the importance of continuous professional development and thus provide periodic training according to the BIM implementation plan.

Stage 3.4: Educational Partnership Implementation

This stage involves fostering strong collaboration with industry partners through projects, internships, and workshops. Professionals can also offer practical training for staff and students to improve their knowledge of BIM tools. Academic-industrial collaborations are also a key component when bringing guest and assistant lecturers to teach BIM exercises and assist students during tutorials on how to apply BIM technologies. It is important to evaluate the impact of industry involvement on student learning and career readiness. It is also important to adjust partnership activities as needed for continuous improvement. In addition, at the programme implementation stage, institutions should encourage inter-department collaboration, which entails dividing resources and developing consistent practices across AECO departments. Such partnership could reduce the repetition and duplication of teaching resources, reducing staff workload. In addition, professionals can keep assistance in developing BIM courses and providing practical training for teachers on BIM tools.

7.7.1.4 Phase 4: Programme Operation and Evaluation

The final phase focuses on assessment and continuous improvement. It involves evaluating the effectiveness of the BIM programme, gathering feedback from stakeholders, and using these insights to make informed adjustments and enhancements, ensuring that the programme remains relevant and impactful.

Stage 4.1: Continuous Evaluation and Monitoring

This stage involves assessing the effectiveness of the BIM programme in achieving its objectives. During this stage, the university should focus on evaluating the initial delivery of BIM courses within the architectural programme. The evaluation includes comparing the outcomes with the university's BIM education propose and vision. Essential steps in this stage involve gathering feedback from BIM students about the module content, learning materials, and their overall educational experience. Additionally, educators closely monitor the module's implementation, tracking students' progress, performance, and any need for additional training or support.

To gain a holistic perspective, seeking input from industry professionals is recommended at this phase to identify potential adjustments based on their insights. Once the initial integration efforts are reviewed and refined, the cycle can repeat until reaching the final milestone.

Stage 4.2: Programme Enhancement and Innovation

This stage involves using evaluation results in Stage 4.1 to make informed adjustments and enhancements. This phase emphasizes continuous and gradual improvement in the quality, repeatability, and predictability of BIM capabilities within the educational programme. After each revision cycle, the university can take further actions to enhance the BIM programme. These actions may include:

- Incorporating BIM as a fundamental methodology in teaching and learning activities.
- Implementing various software tools across all BIM teaching spaces.
- Providing suitable hardware equipped for BIM applications, with plans for ongoing improvement.
- Creating a collaborative learning environment where students from different disciplines engage with BIM.

- Integrating BIM requirements into the competency matrix for teacher recruitment.
- Embedding BIM concepts and practices into core architectural courses and related disciplines.
- Offering professional presentations of real-world BIM case studies to students.

This iterative process of evaluation and improvement ensures that the BIM programme continually progresses to meet the university's goals and industry standards, ultimately preparing students for success in the field of architectural.

The educators can use the BIM education maturity matrix presented in **Annex 8** to evaluate the progress of BIM education integration. The BIM education maturity matrix refers to the different development and implementation levels of BIM education within educational institutions. The BIM education maturity matrix is measured on a scale of 0 to 4, with level 0 (non-existent) to level 4 (optimising) and provides a clear outline of each level's expected outcomes, processes, and competencies. The aim of each BIM education level is explained below.

- Level 0 of BIM education (None existing). It typically refers to a scenario where no BIM education programme or any BIM-related courses are available in the educational institution. This means that students and faculty members may not be exposed to BIM, its principles, or its applications in the AECO sector.
- Level 1 of BIM education (Initial level). This level focuses on the basic understanding of BIM and its potential benefits. The education at this level aims to introduce students to the concept of BIM and its application in building design, construction, and operation. Students learn about the core components of BIM, such as software, building data management, and collaboration tools. The curriculum at this level may also cover introductory-level BIM software training. This level aims to provide students with a foundational understanding of BIM and its potential impact on the AECO sectors.
- level 2 of BIM education (Defined). At level 2, the educational institution has defined and established a clear BIM education programme, which includes defined objectives, content, teaching methods, and assessment criteria. The BIM education programme is integrated into the overall curriculum, and the educational institution has a dedicated team responsible for BIM education. At this level, the educational institution is committed to the continuous improvement of BIM education and regularly evaluates and updates the BIM education programme based on student and industry feedback. The institution also encourages BIM research and innovation and provides resources to support student and faculty development in BIM.

- level 3 of BIM education (Managed and integrated). In level 3, the BIM process is managed and integrated into the curriculum. This means that the school has a clear strategy for incorporating BIM into their education and has established a process for ensuring students receive a consistent level of BIM education. At this level, the curriculum is structured to integrate BIM into various courses, including design, engineering, and construction management, to give students a comprehensive understanding of the technology and its applications. BIM tools and processes are also monitored and evaluated, and improvements are made as necessary to ensure that students are receiving the best possible BIM education. Overall, level 3 indicates that the school is well on its way to achieving a fully mature BIM education program.
- level 4 of BIM education (Optimising). At Level 4, the implementation and integration of BIM into the educational curriculum is considered optimised. This means there is a high level of coordination and collaboration between the various stakeholders involved in BIM education, including students, teachers, industry professionals, and curriculum developers. The BIM education process is well-established, streamlined, and continuously evaluated and improved. Students are equipped with the necessary knowledge and skills to use BIM in real-world projects effectively, and the curriculum is aligned with industry standards and practices. At this stage, BIM education is fully integrated into the institution's overall educational strategy and significantly impacts student success and industry readiness.

7.7.2 A Four-Year BIM-Integrated Curriculum Development

The previous **Section 7.7.1** discussed A Four-Phase Procedure for BIM Programme Development and its gradual implementation into a four-year undergraduate architectural programme. This section outlines what a full plan can achieve after successfully integrating BIM into the Libyan undergraduate architectural programme. The goal is to develop a BIM-integrated curriculum across four academic years, enhancing the curriculum with the following topics:

- Architectural fundamentals: grounding students in historical context and core principles of architectural.
- Collaboration and communication: emphasizing teamwork and stakeholder engagement skills.
- Technological integration: exploring cutting-edge technologies to enhance design capabilities.
- Data management: equipping students with skills for effective information handling.

- BIM tools and modelling: developing proficiency in BIM tools to foster creativity.
- Performance analysis: integrating analytical tools for architectural assessment.
- Professional skills: enhancing communication and project management skills.
- Industry standards: familiarizing students with regulatory frameworks and ethical considerations.

The integration of BIM into the undergraduate architectural education programme in Libya represents a progressive and innovative approach to preparing students for the evolving demands of AECO sectors. This curriculum merges practical BIM skills with foundational architectural principles, ensuring a well-rounded education that addresses both current industry needs and future advancements.

The BIM curriculum is designed around the CDIO (Conceive-Design-Implement-Operate) approach, a globally recognized model for engineering education that emphasizes practical and experiential learning. This framework ensures students develop their skills and knowledge through four distinct, interconnected phases:

- Year 1: Conceive: Focuses on building a strong foundation in architectural principles while introducing basic BIM concepts.
- Year 2: Design: Shifts the focus to the practical application of architectural knowledge using BIM tools.
- Year 3: Implement: Delves into more advanced BIM techniques and implementation strategies for complex projects.
- Year 4: Operate: Focuses on integrating BIM into real-world architectural projects, emphasizing professional preparation and interdisciplinary teamwork.

Beyond the CDIO framework, the curriculum draws on additional resources to foster a holistic learning experience:

- TPACK Framework: Aligns with the TPACK (Technological Pedagogical Content Knowledge) framework (Details in **Table 7.3**). This ensures a balanced educational experience where students not only learn BIM tools but also understand how to apply them effectively within pedagogical frameworks.
- Periodic Table of BIM: This visual and organizational tool categorizes BIM elements systematically, aiding educators in planning and implementing BIM content effectively throughout the curriculum (**Annex 6**).
- The AiC BIM Body of Knowledge (BOK): This resource details essential competencies and skills for effective BIM practice. It provides a structured guide covering all critical aspects of BIM, from basic concepts to advanced applications.

By integrating the AiC BIM BOK, the curriculum ensures comprehensive coverage of BIM-related knowledge areas, preparing students for professional excellence.

The detailed implementation plan for the Four-Year BIM-Integrated Curriculum is presented in the following section.

Year 1: Conceive and Technological Foundations

In the first year, the curriculum focuses on the Conceive Phase, emphasizing the foundational aspects of architectural principles and the introduction of BIM concepts. This year is critical for establishing a solid base in both traditional architectural skills and modern BIM technologies.

Students begin by developing a profound understanding of core architectural principles and design. They engage in detailed architectural sketching and rendering, learning to accurately depict building components and their interactions within a broader context. Alongside these traditional skills, students are introduced to the value and impact of BIM in the AECO sector. This includes recognizing how BIM transforms the architectural profession and projects.

Technological knowledge is a key focus, with students developing basic BIM software skills. They learn to navigate and manipulate models within BIM software, gaining practical insights into this transformative technology. Active learning is promoted through interactive software tutorials, enabling students to visualize and explore architectural concepts using BIM tools.

Pedagogically, the curriculum fosters collaboration through group projects that utilize BIM models. Students engage in comprehensive discussions on the theoretical foundations of BIM technology, supported by industry case studies that showcase real-world applications. By integrating these elements, students develop an appreciation for the theoretical and practical aspects of BIM without feeling overwhelmed.

By the end of the first year, students should:

- Demonstrate proficiency in architectural sketching and basic drawing techniques.
- Apply basic BIM terminology and workflow concepts.
- Navigate BIM software interfaces and perform basic model manipulation tasks.
- Create accurate and detailed 2D drawings suitable for BIM integration.

Year 2: Design and Practical Application

The second-year transitions to the Design phase, where students move from theoretical foundations to practical applications of BIM concepts. This year emphasizes applying architectural knowledge to create 3D BIM models and integrating environmental design considerations.

Students apply their understanding of architectural principles to basic 3D BIM modelling, mastering the primary tools for 2D sketching and advancing their skills in 3D creation. They are introduced to environmental design concepts and basic analysis tools within BIM software, focusing on the impact of design decisions on building performance. This exploration of environmental design enhances their ability to create sustainable and efficient architectural solutions.

Communication and collaboration are central themes in the second year. Students further develop their abilities to present and discuss BIM models effectively, utilizing renderings and walkthroughs to communicate their designs. Experiential learning in small design studios fosters teamwork, encouraging students to collaborate and provide peer feedback on BIM models.

Pedagogically, project-based learning encourages design exploration with BIM, promoting iterative modelling and design thinking skills. Students are encouraged to apply their theoretical grounding in practical settings, reinforcing their understanding of BIM and architectural concepts.

By the end of the second year, students should:

- Master primary tools for 2D sketching and 3D creation.
- Apply architectural concepts to basic 3D BIM modelling.
- Explore environmental design concepts and basic BIM analysis tools.
- Understand the impact of design decisions on building performance.
- Develop effective communication skills for BIM presentations and discussions.
- Practice teamwork and collaboration within small design studios.

Year 3: Implement and Advanced Techniques

In the third year, the curriculum enters the Implement phase, where students delve deeper into BIM implementation strategies and advanced techniques. This year is pivotal for understanding the multifaceted capabilities of BIM and preparing for more complex architectural challenges.

Students gain a comprehensive understanding of BIM implementation strategies and workflows, exploring industry standards such as COBie (Construction Operations Building information Exchange) and IFC (Industry Foundation Classes). They master advanced 4D (scheduling) and 5D (cost estimation) BIM tools, developing the skills necessary for effective project management and optimization.

The curriculum introduces parametric design skills using BIM technology, allowing students to explore more sophisticated design solutions. Collaborative learning activities using online BIM platforms enhance their ability to work in teams, manage conflicts, and communicate effectively in complex project environments.

Pedagogically, problem-solving scenarios are designed to apply BIM workflows, fostering critical thinking and analytical skills. Students engage in interdisciplinary design studios, collaborating with peers from other disciplines to tackle medium-scale design projects. This hands-on experience is crucial for understanding the real-world applications of BIM and preparing for professional practice.

By the end of the third year, students should:

- Understand BIM implementation processes and various project delivery methods.
- Manage and share BIM models within teams and with clients.
- Explore relevant BIM standards, best practices, and legal implications.
- Master advanced 4D and 5D BIM tools for project analysis and optimization.
- Apply these tools to medium-scale design projects.
- Participate in interdisciplinary design studios and collaborate with other disciplines.
- Develop conflict resolution and communication skills for complex projects.

Year 4: Operate and Professional Mastery

The fourth and final year corresponds to the Operate phase, focusing on professional preparation and the application of cumulative knowledge and skills to large-scale, real-world projects. This year is designed to bridge the gap between academic learning and professional practice.

Students apply their accumulated knowledge to solve real-world architectural design challenges in complex projects. They master interdisciplinary teamwork and data exchange using advanced BIM tools like 6D (sustainability) and 7D (facility management). Advanced communication skills are developed for managing project information and stakeholder relationships, ensuring students are prepared for professional interactions.

The curriculum emphasizes hands-on experience in managing and delivering BIM-integrated projects in a simulated professional setting. Role-playing activities simulate collaboration with various stakeholders, allowing students to practice communication and project management skills in realistic scenarios. By integrating advanced BIM tools such as virtual reality and artificial intelligence, students explore cutting-edge technologies that enhance their design capabilities.

Pedagogically, the curriculum provides opportunities for self-reflection on BIM project management and communication. Students engage in real-world case studies, analysing project data and outcomes to develop problem-solving skills. This holistic approach ensures they are well-prepared for professional practice, with a deep understanding of both theoretical and practical aspects of BIM.

By the end of the fourth year, students should:

- Successfully integrate BIM into the design, construction, and delivery of large-scale architectural projects.
- Collaborate effectively within diverse project teams and manage interdisciplinary data exchange.
- Effectively manage project workflows, document communication, and present information to stakeholders.
- Apply BIM knowledge and skills to solve real-world project challenges and manage interdisciplinary teams.

Table 7.3: Four-Year BIM-Integrated Curriculum

Year	CDIO Phase	Content Knowledge (CK)	Technological Knowledge (TK)	Pedagogical Knowledge (PK)
1	**Conceive**	- Grasp core architectural principles and design. - Recognize the benefits of BIM in the AECO industry (Architecture, Engineering, Construction, and Operation).	- Develop basic BIM software skills (navigation, modelling).	- Introduce active learning through interactive software tutorials. - Foster collaboration through group projects using BIM models.
2	**Design**	- Apply architectural concepts to create 3D BIM models.	- Introduce environmental design concepts and BIM simulation tools (e.g., energy analysis). - Utilize BIM software for effective communication (renderings, walkthroughs).	- Utilize project-based learning to encourage design exploration with BIM. - Encourage peer review and feedback on BIM models.
3	**Implement**	- Gain a comprehensive understanding of BIM implementation strategies and workflows.	- Explore industry standards like COBie and IFC. - Master advanced 4D (scheduling) and 5D (cost estimation) BIM tools.	- Implement collaborative learning activities using online BIM platforms. - Design problem-solving scenarios for students to apply BIM workflows.
4	**Operate**	- Apply accumulated knowledge to solve real-world design challenges in complex projects.	- Master interdisciplinary teamwork and data exchange using advanced BIM tools. - Develop assessment strategies for evaluating BIM models and project outcomes. - Gain hands-on experience in managing and delivering BIM projects in a simulated professional setting.	- Implement case studies with real-world project data and BIM deliverables. - Provide opportunities for peer assessment and feedback on BIM project deliverables. - Utilize role-playing activities to simulate collaboration with various stakeholders (architects, engineers, contractors).

7.8 Summary

This chapter presents the primary outcomes of this research in the form of a developed excellent framework for BIM education oriented toward undergraduate architectural education in Libya. The developed framework was based on the literature review findings and the collected quantitative and qualitative data. The implementation of the BIM educational framework affects the architectural curriculum programme, educators, and students. The developed BIMEXAE framework was implemented alongside the specification of its purpose, objectives, and intended learning outcomes. The BIMEXAE framework addressed the selective or gradual introduction of BIM in the undergraduate architectural programme of the four academic year programme, based on four integration stages that give greater flexibility to gradual integration and improvements. The first and second phases consist of planning, preparation, and diagnosing the programme before the deployment of BIM in the programme. The third phase is designing the program, while the fourth phase is the implementation of BIM in the university. Phase five is the review of the programme to continuously improve quality, repeatability, and predictability within BIM capabilities.

This study focuses on architectural education in Libya; the case study is anticipated to limit and define the applicability of the framework presented in this chapter since it is an example of nascent BIM implementation in architectural education in Libya. Nonetheless, it is hoped that this framework can be served as the guiding principle for educators, practitioners, and other specialists who intend to introduce BIM education in their current engineering education fields, enabling them to develop a more suitable AECO education strategy to address the challenges they may face (or have faced) by adopting BIM education.

Chapter 8: BIMEXAE Framework Assessment based on Consultations with Architectural Educators

This chapter presents the findings from consultations with architectural educators aimed at assessing the BIMEXAE framework in the context of integrating BIM within architectural education in Libya. Through a questionnaire-based survey (See a copy of the questionnaire in **Annex 5**), Libyan architectural educators assessed the framework's components, value, design, applicability, suitability, and effectiveness. The following sections detail the assessment process and its outcomes.

8.1 Overview of BIMEXAE Framework Assessment

Assessing the BIMEXAE framework through consultations with architectural educators is crucial for evaluating its integration within architectural education in Libya. Incorporating feedback from educators as the primary users responsible for delivering the curriculum it is ensures the framework's relevance and effectiveness, identifying areas for improvement and facilitating successful implementation (Creswell, 2014; Van den Brink, 2003).

Considering the time constraints of PhD research, this study employed a survey as a practical method for consultation with potential users (educators in Libyan architectural education). Surveys offer a quick, inexpensive, and convenient way to gather user feedback (Eddy et al., 2012).

Educators' perspectives are crucial in assessing the BIMEXAE framework's applicability and usability.Their insights can reveal gaps or areas for improvement, ultimately leading to a framework that aligns with real-world needs and expectations in Libyan architectural education. The framework has received positive feedback from academic experts in Libyan architectural education. Their suggestions and insights have enhanced the framework's usability, applicability, and overall reliability. All participants in this consultation process were lecturers with a minimum of three years of experience and a strong recognition of BIM education's importance for AECO sectors.

8.2 Assessment Process of BIMEXAE Framework

To assess the BIMEXAE framework's integration within architectural education in Libya, an interactive guide was developed to summarize the research process, key findings, and details of the framework. This guide, created in Microsoft Word, was designed to facilitate the consultation process. To ensure the guide was clear and comprehensive for independent participants, a pilot study was conducted with five PhD students. Feedback from this pilot study was used to refine the guide before its final deployment (The final version of the survey is included in **Annex 5**).

The survey was structured in two sections. The first section included general questions to establish participant profiles. The second section focused on the BIMEXAE framework, prompting participants to evaluate its value, content, design, applicability, effectiveness, and suitability for Libyan architectural education. The survey concluded by inviting participants to offer suggestions for further improvement. Participants were chosen based on their knowledge and ability to provide informed opinions on BIM. The survey's first section assessed BIM expertise by inquiring about participants' familiarity with the BIM concept and the possession of any official BIM credentials.

The researcher personally distributed the questionnaires during visits to Libyan architectural universities. This approach ensured a feasible number of responses. The survey period spanned two months, from October 11th to November 15th, 2022. During this timeframe, 27 participants manually completed the survey. The detailed survey results are presented in the following section.

8.3 Results of BIMEXAE Framework Assessment

The survey results conducted using questionnaires were examined and discussed in this section. A total of 27 persons responded to the survey, and their responses were statistically analysed using frequency distribution analysis. The results were presented in the following two sections with related discussion.

8.3.1 Part 1: General Information

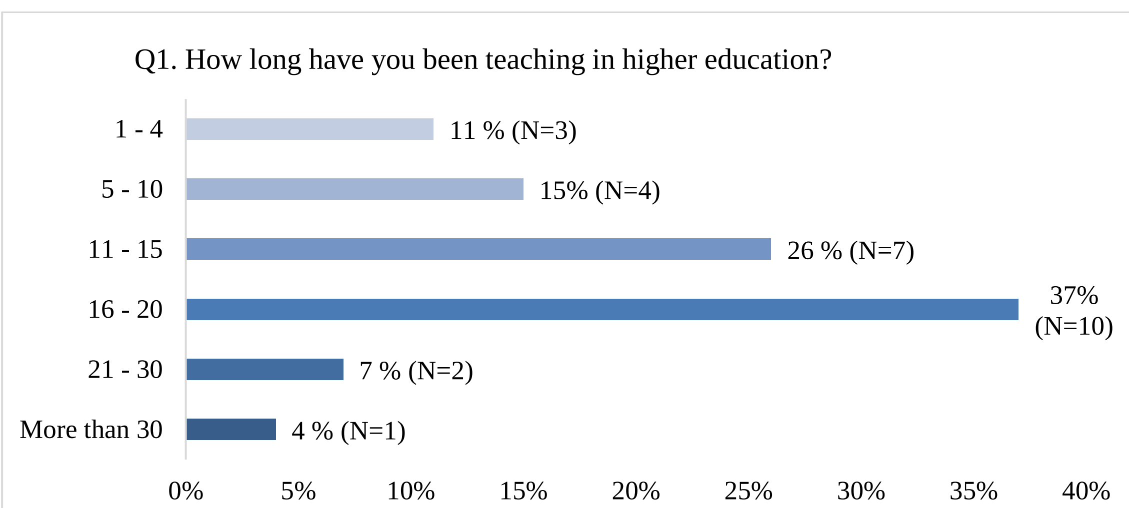

Figure 8.1: Teaching experience of the respondents in Survey C

Teaching experiences (Q1). **Figure 8.1** shows that 37% (N=10) of the respondents have been teaching at higher education levels for 16-20 years, 26 % (N=7) of the respondents have been teaching at higher education levels for 11-15 years, 15% (N=4) of respondents have been teaching at higher education levels for 5-10 years, 11 % (N=3) of the respondents have been teaching at higher education levels for 1-4 years, 7 % (N=2) of the respondents have been teaching at higher education levels for 21-30 years, and 4 % (N=1) of the respondents have been teaching at higher education levels for more than 30 years.

These results indicate that a significant proportion of the participants in the sample have been working in Libyan architectural education for more than 15 years, with extensive experience in teaching and learning approaches and opportunities to use different techniques and technologies in their teaching programme. It is expected that their years of experience in the teaching field can effectively guide their decisions regarding the implementation of the proposed framework in architectural education since most of the respondents are lecturers in the department of architectural.

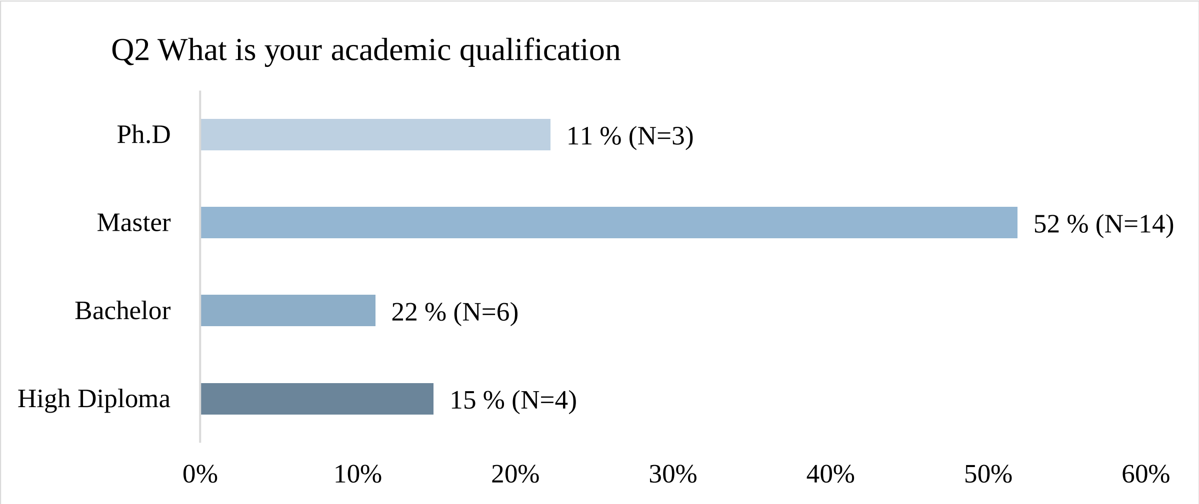

Figure 8.2: Academic qualification of the respondents in Survey C

Qualification (Q2). The analysis of the participants' education qualifications showed that 52 % (N=14) of the respondents had a master's, 22 % (N=6) of the respondents had a Ph.D. and 15 % (N=4) of the respondents had a higher diploma; 11 % (N=3) of the respondents had graduated with a bachelors (See **Figure 8.2**). The analysis showed that most of the participants had been educated to at least a master's level of education. Academic qualification and years of experience in a given field are necessary parameters when making decisions on the implementation of a new technology, especially in the education sector. Most of the respondents have been educated to the level of master in their respective fields, hence, they are expected to be in a better position to know the likely benefits of implementing the proposed framework in their teaching and learning activities.

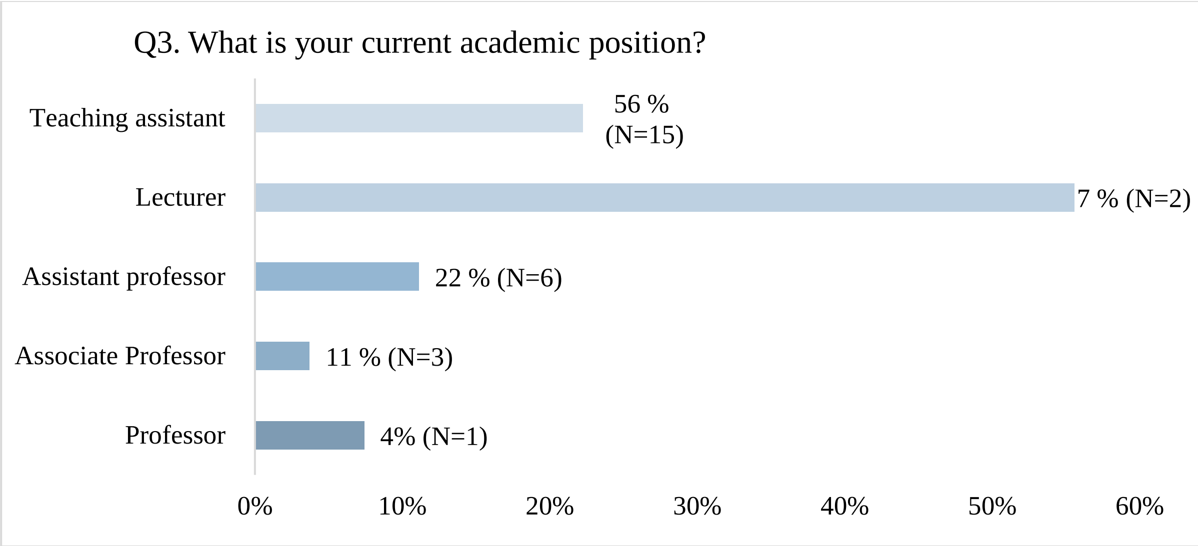

Figure 8.3: Current academic position of the respondents in Survey C

Academic position (Q3). **Figure 8.3** showed that most of the respondents in the survey were lecturers 56 % (N=15) while 22 % (N=6) of the respondents were teaching assistants. 11 % (N=3) of the respondents were assistant professors, 7 % (N=2) were professors, and only 4% (N=1) were associate professors. This indicates that the majority of the participants in the study have lecturer positions and most of them have extensive experience in teaching in their field of speciality; hence, their perspectives on academic teaching, and performance may be reliable, and their judgment considered reasonable.

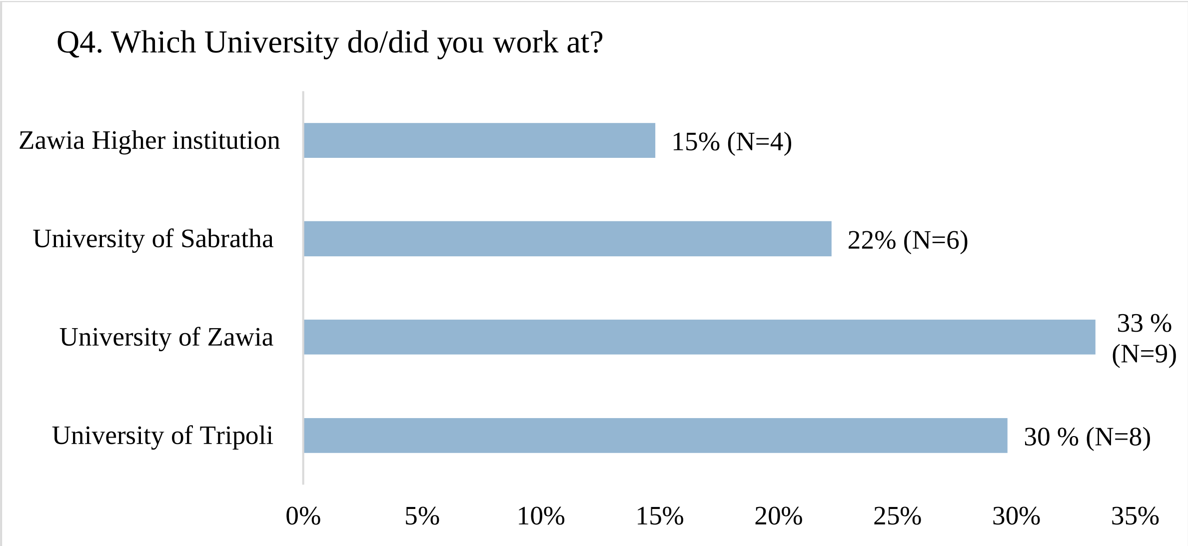

Figure 8.4: Job placement of the respondents in Survey C

Workplace (Q4). **Figure 8.4** shows that the respondents were mostly sampled from 4 universities with the following distribution: the University of Zawia 33 % (N=9), the University of Tripoli 30 % (N=8), the University of Sabratha 22% (N=6) and the higher education institution of Zawia 15% (N=4). The consideration of respondents from different universities and some of the well-known universities that offer architectural education in Libya is aimed at ensuring that their views and positions on implementing BIM in architectural education are valid. Such decisions can only be valid when the views and opinions of the experts in the field are given priority during the decision-making phase. Hence, it is believed that the views provided by the university lecturers in this study will effectively guide the decision on the use and implementation of BIM in architectural education in Libya.

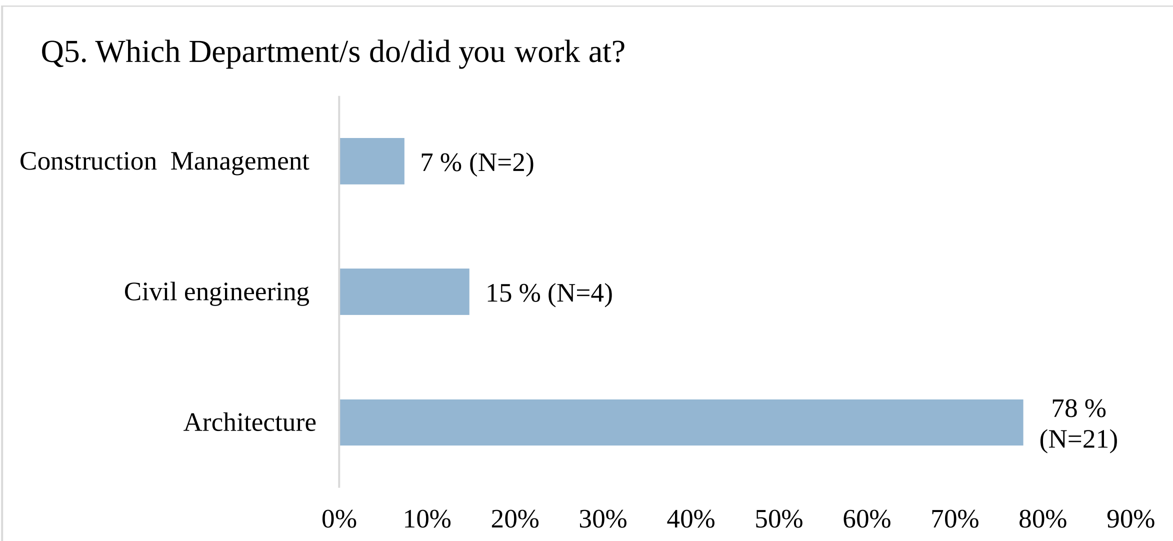

Figure 8.5: Departments of the respondents in Survey C

Department (Q5). The results indicated that 78 % (N=21) of the respondents did or still work in the architectural department, while 15 % (N=4) and 7 % (N=2) of the respondents work in the civil engineering and construction management departments, respectively (**Figure 8.5**). This implies that most of the participants in the survey work or had worked in the architectural department, which can be very effective as the study focuses on BIM adoption and implementation into architectural education. Hence, their decisions on the use and implementation of BIM in architectural education can be considered effective and necessary during the decision-making phase.

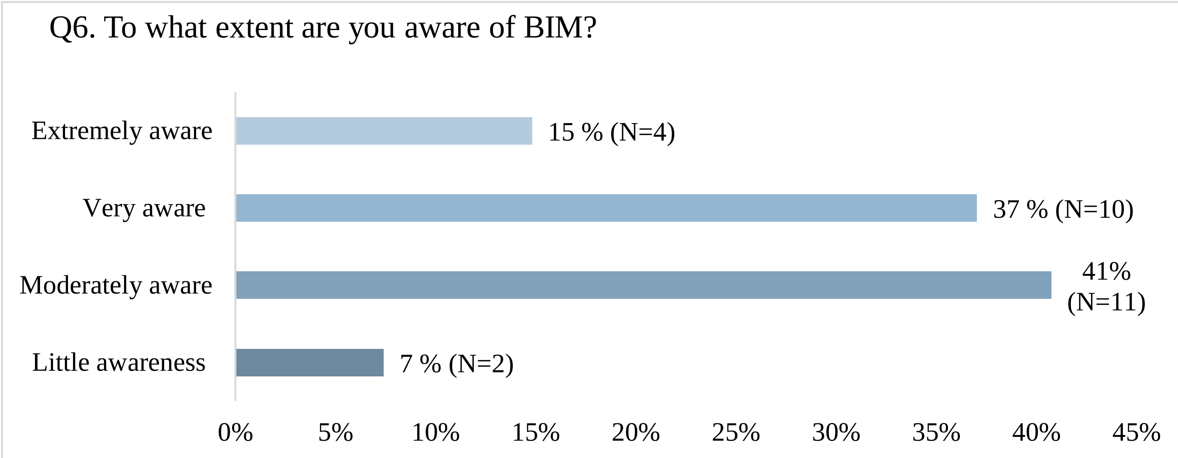

Figure 8.6: Awareness levels of the respondents on BIM in Survey C

BIM awareness (Q6). Regarding awareness of BIM, 41% (N=11) of the respondents agreed to have moderate awareness of BIM, while 37 % (N=10) of the respondents had high levels of awareness of BIM. Respondents with extreme levels of awareness of BIM accounted for 15 % (N=4) of the respondents, while 7 % (N=2) of the respondents had little awareness of BIM. The results presented in **Figure 8.6** indicated that a large number of the participants were between moderately aware and very aware of BIM which is highly useful given that the study's focus is on the integration of BIM in architectural education. Consequently, their decisions about the application of BIM in architectural education can be seen as successful and crucial during the decision-making stage. However, educators need a greater BIM awareness campaign to improve their knowledge and use of BIM in their respective fields. With a focus on the implementation of BIM in architectural education in Libya, improving the level of awareness of BIM among architecture lecturers in Libya will impact their decisions on the adoption and implementation of BIM in architectural education in Libya.

8.3.2 Part 2: Framework Assessment Outcomes

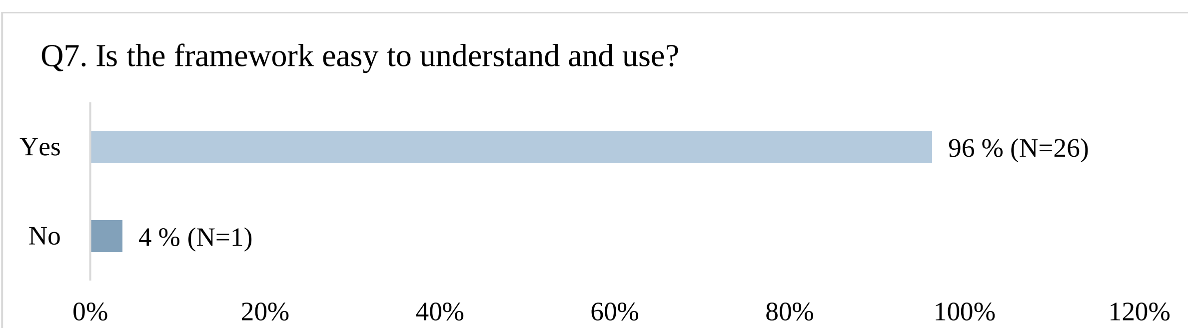

Figure 8.7: Ease of understanding of the framework according to participants in Survey C

Framework value (Q7). The respondents were asked to provide their views on the ease of understanding and use of the BIM framework. **Figure 8.7** shows that almost all the respondents found the BIM framework easy to understand and use, as 96 % (N=26) of the total respondents affirmed that the framework can be easily understood and used, while only 4 % (N=1) of the respondents found it difficult to understand and use. This is an expected observation because the respondents for this study were selected from different fields of engineering where they must have been exposed to some of the components of the framework during their training; hence, the understanding and use of the framework may not be a major issue to its implementation among the studied respondents.

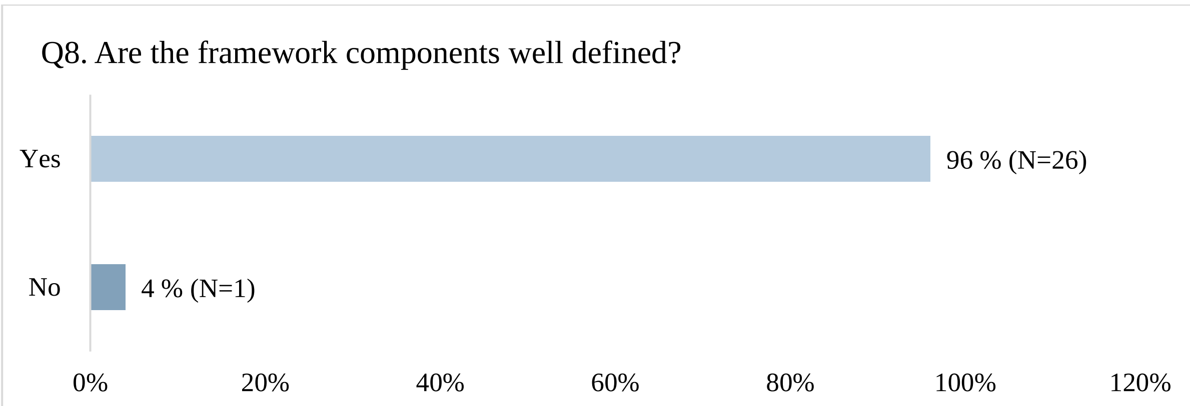

Figure 8.8: Definition of the components of the framework according to participants in Survey C

Framework Contents (Q8). Being that the BIM framework is made up of many components working together to achieve a common goal, the respondents in this study were requested to provide their views on the presentation and definition of each of the components of the BIM framework. As seen in **Figure 8.8** most of the respondents 96 % (N=26) believed that the components of the framework were suitably defined to ease understanding and use, while only 4 % (N=1) were not satisfied with the presentation and definition of the components of the BIM framework. As expected, a good presentation and definition of the components of the BIM framework are necessary conditions for its understanding and implementation. Hence, the high rate of acceptance of the appropriateness of the definition of the components of the framework was evidenced by the high level of its understanding and usage seen in **Figure 8.7**.

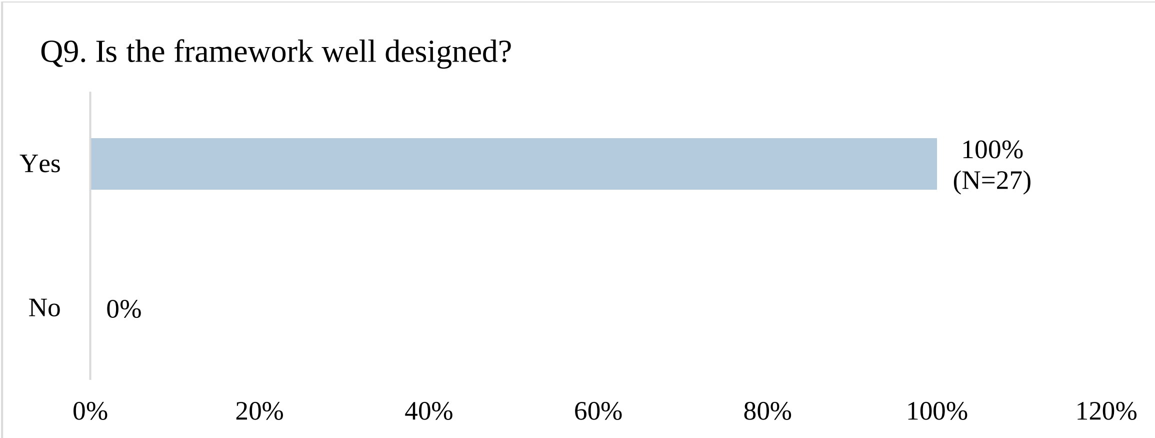

Figure 8.9: The design of the framework according to participants in Survey C

Framework design (Q9). Regarding the design of the framework, all the respondents 100% (N=27) believed that the BIM framework was adequately designed and presented (**Figure 8.9**). The proper design of the framework entails that the components have been well defined and associated with easing its understanding and usage among the respondents. Therefore, the wide acceptance of the framework among the respondents is a testament to the proper definition of its components, which assisted in the understanding and using the framework among the respondents.

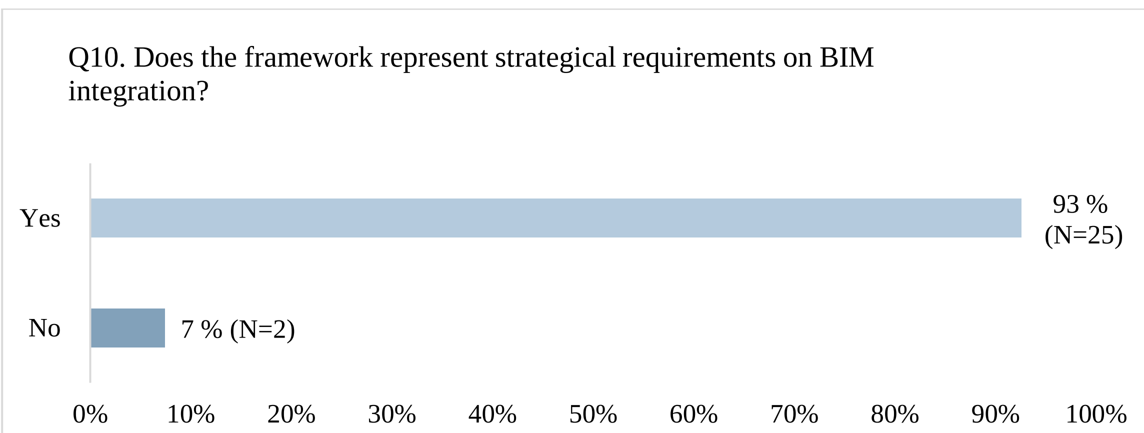

Figure 8.10: Applicability of the framework according to participants in Survey C

Framework applicability (Q10). The integration of a framework into BIM demands that the framework must meet specific strategic requirements for BIM integration. The respondents in this study were requested to provide their opinions on the framework in terms of meeting the strategic requirements for BIM integration. **Figure 8.10** shows that a high number of respondents 93 % (N=25) considered the framework suitable for BIM integration as it met most of the strategic requirements. However, a few respondents 7 % (N=2) did not believe that the framework has sufficiently met the strategic requirements for BIM integration. A high number of respondents who believed the components of the framework have been well defined and understood also considered it suitable for integration on BIM to ease their jobs, while those that are not yet satisfied with the definition of the components of the framework are still hesitant on its suitability for BIM integration.

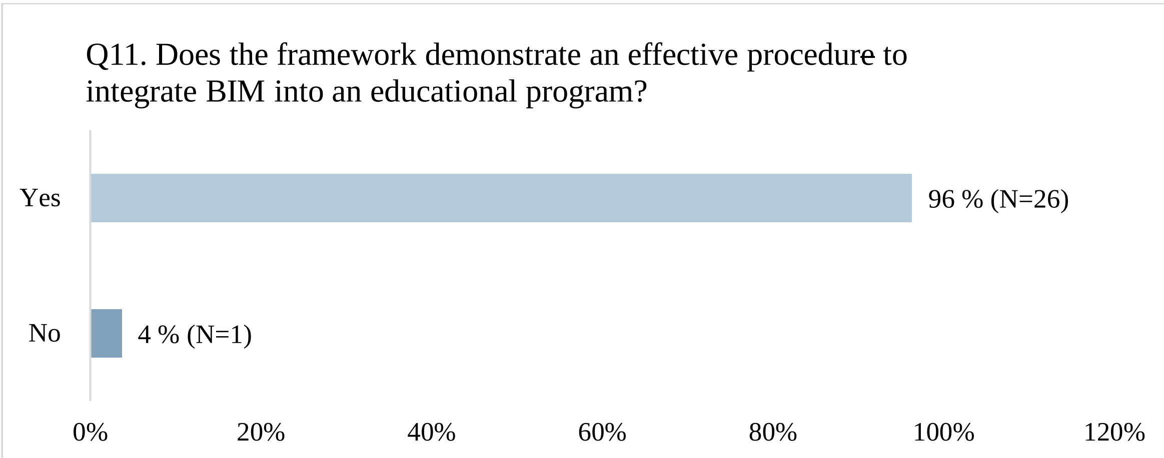

Figure 8.11: Procedural effectiveness of the framework for BIM integration according to participants in Survey C

Framework effectiveness (Q11). For the framework to be integrated into an architectural educational programme, it must demonstrate some levels of procedural effectiveness that will facilitate the seamless integration into an existing model. The opinion of the respondents was sought on the level of effectiveness of the model in terms of an implementable procedure that will guide the integration into an architectural education programme. The opinion of the respondents, as seen in **Figure 8.11,** showed that most of the respondents 96 % (N=26) consider the framework procedure effective for integration into an architectural programme. In comparison, a few of the respondents 4 % (N=1) believe that the procedure of the framework is not yet suitable for integration into an architectural programme. This hesitance could be because they are yet to understand the concepts of the framework due to the inefficient definition of the components of the framework; the hesitant respondents demand more explanation of the components of the framework to better understand its use before it can be integrated into an architectural education programme.

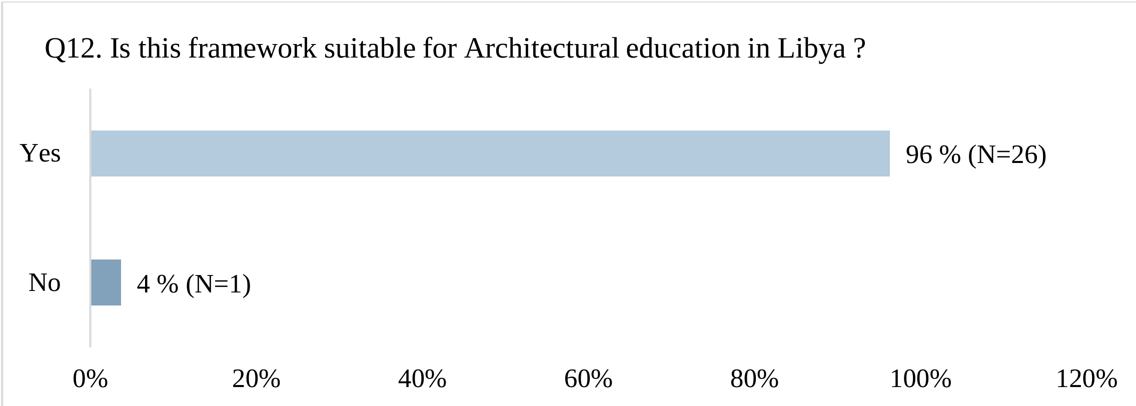

Figure 8.12: Suitability of the framework for architectural study in Libya according to participants in Survey C

Framework suitability (Q12). The perspective of the respondents was sought on the suitability of the framework for architectural education in Libya. The responses in **Figure 8.12** showed that almost all the respondents 96 % (N=26) agreed with the suitability of the framework for architectural education in Libya, while about 4 % (N=1) of the respondents objected to the suitability of the framework for architectural education in Libya. Every field of engineering has specific requirements to guide the implementation of certain policies; hence, the opinion of the experts in such fields always matters when making certain policies. The overwhelming support for the suitability of the model for architectural studies in Libya may suggest that its components have been reasonably defined for improved understanding and implementation among potential users. However, a small percentage of the respondents (4 % N=1) still demand further explanations on the components of the framework before certifying its suitability for architectural studies in Libya.

Q13. What are your suggestions for improving this framework for architectural education in Libya?

The majority of the respondents of this study have overwhelmingly supported the suitability of the framework for architectural education in Libya, which is a testament to their belief that the framework is easy to understand and implement due to the efficient definition of its components. However, few respondents believed that the model components are yet to be efficiently defined, and their understanding of the model in terms of ease of implementation is still limited. Therefore, further improvements have been made to improve the framework, which can be summarised as follows.

- Detailing the definition of components: To improve the understanding of the few respondents who found the framework challenging to understand, it may be necessary to provide more detailed definitions of the components of the framework. This has been achieved by creating supplementary materials that provide further explanations and examples of each component.

- Flexibility in implementation: The implementation of BIM in architectural education in Libya requires a level of flexibility to facilitate a smooth transition without major challenges. Therefore, the framework has been designed to allow for adaptation to different learning styles, curricula, and skill levels.
- Gradual adaptation: The implementation steps of BIM should be broken down to ensure a gradual adaptation from the early to professional levels of the implementation process. This has been achieved by developing modules that cover different levels of complexity, allowing students to develop their skills gradually.
- Updating learning outcomes: The integration of BIM into the existing curriculum may require an update on the existing learning outcomes to accommodate the BIM-related aspects. This has been achieved by developing learning objectives that align with the BIM curriculum, and an assessment of students' skills and understanding of BIM can be used to evaluate the effectiveness of the updated curriculum.
- Providing practical experience: BIM education is best learned through practical experience. Therefore, the BIM education framework has included opportunities for students to work on real projects as part of their coursework or through internships. This will allow students to apply their learning in real-world scenarios and gain practical experience in the use of BIM tools and techniques.

8.4 Summary

This chapter presents the consultation procedures undertaken to assess the efficacy and suitability of the developed BIMEXAE framework within the context of this study. Various facets of the framework, including its ease of understanding, components definition, framework design, framework applicability, procedural effectiveness of the framework, and suitability for architectural education in Libya, were subjected to justification through the perspectives obtain from respondents involved in the study. Most respondents (>90 %) supported and encouraged the developed framework and its suitability for architectural education in Libya. In addition, the development frameworks have been improved by providing more detailed definitions of its components, maintaining flexibility in implementation, breaking down implementation steps, updating learning outcomes, and providing practical experience.

Chapter 9: Conclusion

The final chapter provides a summary of the study. It outlines the research's aim and objectives, detailing how those objectives were successfully attained throughout the investigation and summarising the corresponding findings. Furthermore, the chapter expounds on the study's contribution to knowledge. It includes the overarching conclusions of the research and presents a condensed overview of potential avenues for future research.

9.1 Achievement of the Research Aim and Objectives

The research conducted for this PhD study aims to develop a BIMEXAE framework for BIM competence-oriented architectural education in Libya. This aim has been achieved through the following four objectives:

Objective 1: To critically review the status of BIM and identify best practices for its implementation in AECO sectors and architectural education.

The literature review covered in Chapter 2 of this dissertation fulfilled the first objective of this study. The first objective under consideration is to identify and emphasize the basics of the study; the first task under this objective is to investigate the theoretical underpinnings of this research by looking at the current trend of the use of digital technology in architectural education and practices with a focus on BIM implementation in the practical and academic sectors. This objective focuses on the transition from the educational setting to the workplace to identify the gaps and difficulties that limit the application of BIM in both academic settings and professional practice. Based on the literature review, the following conclusions were highlighted.

- BIM definition and capabilities: BIM goes beyond just modelling; it utilises IT for data collection, computer-aided visualization, and simulation analysis. Its functionalities and tools offer significant advantages throughout the project lifecycle.
- Global adoption and awareness: BIM awareness and adoption are increasing worldwide but developing countries face challenges due to resource limitations and awareness gaps.
- Barriers to implementation: Lack of skilled workforce, standardized approach, high software costs, and legal issues hinder BIM implementation.
- BIM education integration phases: Architectural schools have gone through four phases of integrating BIM: transition from AutoCAD, standalone course, cross-disciplinary core curriculum, and BIM-enabled architectural education.

- Teaching methods and recommendations: Standalone and integrated approaches are both relevant, with emphasis on design studio courses. BIM learning should consider both knowledge and practical skills.
- Policy considerations: Policies should be formulated based on the perspectives of young professionals and consider their teaching experience and qualifications.

Objective 2: To investigate and evaluate the status of BIM implementation and its associated challenges within Libyan AECO sectors and architectural education.

This objective was achieved through a literature review and surveys, which included questionnaires. The results of this objective are presented in detail in Chapters 3, 5, and 6.

Chapter 3 provides a detailed overview of the context of Libya as a research context. It reviews the country's background, its AECO sectors, and the state of BIM implementation in the nation. This exploration uncovers the unique challenges that impede BIM's effective integration, including limitations in expertise, training opportunities, and incentives. In addition, Libyan universities focus on theoretical knowledge and design principles but need to integrate emerging technologies and emerging practices. Integrating digital technologies, including BIM, can revolutionise the Libyan AECO sectors and enhance productivity.

Chapter 5 shifts the focus on BIM practices in Libya, with particular emphasis on the AECO sectors. The Survey A conducted in this chapter collects the perceptions of professionals working in the Libyan AECO sectors.

- **Summary of the Findings of Survey A with AECO Professionals**

Survey A aims to identify the current status of BIM in the Libyan AECO sectors and to identify the requirements of professionals regarding BIM knowledge and skills that new graduates should have. The following conclusions were highlighted from a survey with professionals.

- There is currently a lack of BIM awareness among Libyan professionals, as most are currently moderately aware of BIM. Therefore, there is a need for more workshops and professional and academic courses to increase BIM awareness among professionals.
- Regarding BIM skill acquisition, most of the participants acquired BIM skills through self-learning. This means that most participants lack adequate BIM training, leaving them without adequate practical skills to produce a complete BIM model. The incentives will encourage professionals to sharpen their skills by

enrolling in training programmes and attending seminars and workshops rather than self-sponsoring.

- The Libyan construction sector is still in the initial phase of BIM adoption due to a lack of BIM-competent workforce in companies; the implementation of BIM relies on outsourcing staff competency, which does not support long-term demands.
- Among non-BIM users, organizations intend to adopt BIM technology in the near future. The results of survey A indicate that participants are willing to adopt BIM in their organisations, which shows that the current situation may change in the future and that they may adopt BIM technology.
- Regarding the importance of BIM use in the AECO sectors, most respondents agreed that BIM is extremely important to implement in the AECO sectors in Libya.
- As per the respondents, the major challenge facing BIM adoption in Libya is the lack of appropriate training, lack of awareness, lack of government support, and lack of skilled workforce are the significant challenges to BIM adoption in the Libya AECO sectors.
- Respondents believe that the primary key drivers for BIM adoption in the AECO sectors in Libya are the provision of appropriate staff training, BIM mandate by the government, and appropriate support.
- There is a lack of BIM training and learning materials in organizations. As indicated by most participants, their organizations do not provide BIM training programmes for their staff, which can load more costs for organizations and staff to have BIM training courses.
- In terms of assistance needed to implement BIM, most respondents stated that their organization needed assistance to implement BIM. This is due to the lack of BIM specialists in the organisation to lead BIM adoption.
- The importance of BIM education for architectural education: Respondents considered integrating BIM into architectural education programmes extremely important, highlighting the need to adapt BIM education based on sector demands.
- Expectations for graduates: Respondents expect new graduates to have a combination of BIM practical skills and theory, emphasizing the importance of a balanced skill set.
- BIM curriculum design and development: The majority of respondents believe that curriculum design and development are essential for effective BIM education.
- Academic and professional partnerships: Most respondents agree that universities should prioritize partnerships with industry stakeholders to enhance BIM education opportunities for students.

Chapter 6 extends the investigation to architectural education in Libya. The Survey B conducted in this chapter collects the perceptions of educators working in Libyan architectural education. It examines the current state of BIM education integration within architectural programmes.

- **Summary of the Findings of Survey B with Architectural Educators**

Survey B aimed to identify the status of BIM education in Libyan universities; the survey focused on academics who work in Libyan architectural education. Based on the survey with academics, the following conclusions were highlighted.

- There is currently a lack of a standardized BIM education curriculum and well-defined prerequisites for the BIM education integration process in architectural education in Libya. Most institutions have neither a strategy for adoption nor a plan for implementation in the various areas of architectural curricula.
- The level of awareness of BIM among academics is still low as most respondents are mildly or moderately aware of BIM, so educators need a greater awareness campaign.
- The BIM skills of educators should be improved by providing them with opportunities to further their skills through training and workshops. The provision of incentives will encourage teachers to sharpen their skills through enrolling in training programmes and attending seminars and workshops rather than self-sponsoring.
- BIM should be an integral part of architectural courses, as per the respondents. In addition, most of the participants are willing to have a BIM course in their departments. Hence, BIM should be introduced in the first academic year to allow students to practice through their studies and graduate with a professional level of proficiency.
- Most respondents believe that BIM is a relevant and important tool in architecture that must be considered a relevant aspect of architectural education that should form part of its curriculum.
- The existing curriculum in most universities should be restructured to integrate BIM with the existing modules.
- Most respondents believe universities are not yet ready to integrate BIM into their programmes due to a lack of strategic planning and resources. This is the major reason for the lack of awareness of BIM among most of the interviewed participants in this study. Most of the universities in the study area still lack the necessary software, hardware, facilities, staff, and learning resources to incorporate BIM.

- The respondents believed that the lack of awareness and reluctance to change the existing curriculum are the major challenges facing BIM education in Libya. They also identified a lack of qualified staff, systems, computers, and learning tools as other challenges mitigating the implementation of BIM in Libya.

The outcomes of Survey A and B are then compared to the literature review in order to develop the initial BIMEXAE framework for BIM competence-oriented architectural education in Libya.

Objective 3: To develop a novel educational BIMEXAE framework for BIM integration with architectural education in Libya, with the potential to be generically applicable in other countries.

The result of this objective is covered in Chapter 7. The third objective aimed to create a suitable approach for the integration of BIM within architectural education, which incorporated all the knowledge gained from the literature review and data collection. The major role of the framework is to provide workable solutions that encourage BIM integration in Libyan architectural education specifically and other related programmes in response to the concerns expressed by academics and professionals, as well as the existing state of BIM in Libya. Furthermore, the framework is aimed at guaranteeing a smooth transition from BIM to architectural education.

As indicated by most respondents, BIM implementation in Libyan architectural education is still at the initial stage. Therefore, there is a need to develop a framework covering different aspects, including institutional integration issues and BIM curriculum content. The framework has been developed and divided into two frameworks:

The first framework aims at the provision of a strategic framework with plainly identified evaluation metrics to encourage institutional planning efforts towards BIM implementation and, specifically its integration into architectural education (See **Section 7.7.1**).

The second framework provides a guide for the full implementation content of the BIM-integrated curriculum for undergraduate architectural education in Libya (See **Section** Error! Reference source not found.).

Objective 4: To assess the BIMEXAE framework through consultations with architectural educators in the context of BIM integration within architectural education in Libya.

The findings of this objective are discussed in Chapter 8. The fourth objective aimed to review the developed framework with Libyan educators and evaluate the components, value, design, applicability, suitability, and effectiveness of the developed framework using a questionnaire-based survey with Libyan educators. The questionnaire was distributed using a face-to-face approach after visiting some architectural schools in Libya to obtain the responses from respondents. The following conclusions were highlighted.

- No challenges were observed concerning the clarity and organisation of the framework. According to the respondents, the content of the framework was clear, concise, and easy to understand.
- The view of the respondents showed that the framework's application would be effective and have significant advantages for academics, students, and professionals in the future.
- The respondents emphasised the value of the framework's adaptability and how it breaks down the learning outcomes so that universities can understand and implement it gradually with only minor adjustments.
- The adaptability of the framework was demonstrated by successfully applying it to the existing Libyan architectural curriculum. The system showed adaptability and the capacity to be incorporated into a Libyan architectural curriculum.

9.2 Research Conclusion

This study collects a set of conclusions regarding the integration of BIM within undergraduate architectural education based on the literature review and the perceptions of professionals and academics. The key insights gained from these sources are summaries below:

- Crucial integration of digital technologies: This research underlines the crucial role of integrating digital technologies, especially BIM, in architectural education to prepare students for the evolving demands of the AECO sectors.
- Broadening BIM beyond modelling: The study eliminates the conventional perception that limits BIM as just a modelling tool, emphasizing its multifaceted functionalities and diverse tools.
- Global adoption and challenges: Challenging the view of slow adoption, this study showcases the increasing global prevalence of BIM while acknowledging

real-world challenges like workforce skill gaps, inconsistent approaches, high implementation costs, and legal hurdles.

- Evolution of BIM integration in education: The study reveals the dynamic phases of BIM integration into architectural curricula, emphasising the importance of varied educational approaches.
- Balancing tradition and BIM learning curve: This study argues for a balanced approach in undergraduate BIM education, rejecting the perception that traditional knowledge and the BIM learning curve are mutually exclusive.
- AutoCAD paradigm shift: The study challenges the dominance of AutoCAD, indicating a need for a paradigm shift by highlighting its current use in creating 2D drawings.
- BIM awareness: This research calls for an awakening of BIM awareness among Libyan professionals, emphasizing the necessity for workshops and courses to bridge the existing knowledge gap.
- The need for formal BIM training programs: Contrary to self-learning trends, the study advocates for formal BIM training programmes to equip professionals with practical skills through seminars and workshops.
- Transitioning BIM adoption stages: the study recognizes the transitional stage of BIM adoption in Libya's AECO sectors, emphasizing the need for long-term workforce competency.
- The need for educator awareness: Contrary to assumptions about educator awareness, the study highlights the urgent need for increased awareness campaigns among academics regarding BIM.
- Empowering educators through incentives: This study advocates for empowering educators by providing incentives for skill development through training programmes and workshops rather than relying on self-sponsored initiatives.
- BIM integration as academic responsibility: The study positions BIM integration as both a government and academia responsibility, urging adjustments to existing academic curricula to accommodate BIM education.
- Collaboration for effective BIM deployment: the study emphasizes collaboration and integration as keys to effective BIM deployment, calling for its incorporation into all design-related modules.
- Government and professional influence: The study recognizes the substantial impact of government and professional bodies on BIM teaching in schools, emphasizing their crucial role.
- Resource readiness and restructuring: Challenging resource-related constraints, the study urges universities to restructure existing curricula and seek necessary assistance for effective BIM integration, emphasizing early exposure for students.

9.3 The Contribution to Knowledge

This study adds to knowledge by filling a significant knowledge gap by discovering a lack of research on the application of BIM in architectural education and practice in Libya; consequently, the status of BIM implementation in Libya is still unknown. With the gathering of primary data from Libyan professionals and educators, this study filled a gap in the literature by reporting findings about the level of BIM awareness, its implementation, the availability of BIM education, and the difficulties in applying BIM in architectural education and practice in Libya.

This study made a significant contribution by identifying the crucial enabling variables for national BIM deployment through a global survey of the literature on BIM implementation. According to the studied trends of BIM implementation in many nations, central government and public sector leadership, academic leadership, industry leadership, and global impact have been identified as the crucial enabling variables for the deployment of BIM across the nations.

Research findings have also highlighted the necessity of cooperation for the implementation of BIM across the nations. Collaboration can occur between two parties, such as between academics themselves and between professionals and academics. Although collaboration can exist between academia, central government, and the public sector which is optimal for a successful BIM deployment, this is not always the case. Any of these players can significantly benefit from global influence and international cooperation, which will advance BIM globally. This work created a framework for easier deployment of BIM in Libyan undergraduate architectural education. According to the data analysis, a comprehensive framework made up of two frameworks is required to integrate BIM in Libyan architectural education; each framework has a specific objective and directs how each task can fulfil its essential role.

1) A four-phase procedure for BIM programme development provides a strategic framework with clearly identified evaluation criteria to support institutional planning efforts to integrate BIM within architectural education.
2) A four-year BIM-integrated curriculum guides the full implementation of the BIM-integrated curriculum for undergraduate architectural education in Libya.

The framework's assessment process showed that BIM practitioners and experts in the nation concurred with its appropriateness for Libya's architectural education. This framework provides a starting point for the deployment of BIM in Libya. Other strategies are expected to be required as BIM implementation across the nation advances.

9.4 Recommendation and Future Improvements

This section offers recommendations and future improvements for academics interested in BIM education and practice in Libya. The findings of this study highlight the necessity for further research on several specific topics. Given the time range and scope limitations of this investigation, future studies should consider topics that complement or expand upon this study.

- Framework integration in architectural programmes: The framework of this study is recommended for use within architectural programmes in Libya. Academics in architectural departments should be encouraged to embed and expand this framework based on their specific systems. This can be achieved through workshops and training sessions designed to familiarize faculty members with the framework.
- Guidelines for other AECO disciplines: AECO disciplines aiming to integrate BIM into their curricula should use this thesis as a guideline and consider it the foundation for their approach. This involves collaboration with academic committees to adapt the framework to each discipline, ensuring that it meets the specific needs of various AECO programmes within universities.
- Professional development: Professional associations in Libya should organize more BIM-related conferences and symposiums. These events will enhance professional educators' understanding and proficiency with BIM. Regularly scheduled events with expert speakers will provide invaluable knowledge and promote continuous professional development.
- Updating BIM data in Libya: To aid future studies, it is essential to keep BIM data on the Libyan situation up to date. This requires establishing a centralized database managed by a national educational body or consortium, with regular updates mandated from universities and industry partners.
- Continuous feedback and evaluation system: To ensure effective BIM integration into architectural education and practice, a system for continuous feedback and evaluation should be implemented. This system should include developing metrics for assessment, conducting regular surveys, and performing reviews within academic institutions and through national educational oversight.
- Supporting advanced digital technologies in universities is crucial. Allocating budgets for technology upgrades and training programmes will ensure that institutions can provide the necessary tools and environments for effective BIM learning.
- Universities readiness: Universities should assess and enhance their readiness for BIM integration. This involves conducting readiness assessments and developing

training programs for faculty and staff to ensure they are well-equipped to teach and implement BIM.

- Partnerships with industry and academia: Partnerships should be established to facilitate the exchange of practical insights and resources. Formulating formal agreements and collaboration projects with software vendors, market leaders, and top international universities will help align educational practices with innovative BIM methods.

There is a need for interdisciplinary curricula, which calls for the cooperation of AECO disciplines to drive the future development of BIM in architectural education. Developing a new educational paradigm should be approached collaboratively by researchers, institutions, practitioners, and governmental organizations. The initiative to create national BIM educational standards and rules should begin in the public sector, with active participation from educators in architecture and allied fields.

9.5 Further Studies

Given this study's focus on strategies for integrating BIM into architectural education in Libya, it is necessary to consider the study limitations, and the propositions deduced from the research.

- BIM in other disciplines and holistic curriculum review: Future research should investigate BIM integration across various engineering disciplines within universities. A comprehensive review of the entire architectural education curriculum to incorporate BIM is essential, with academics playing a leading role in this review process.
- Impact of Covid-19 and BIM in education: Research should also assess the impact of online learning during COVID-19 on BIM education. This involves using mixed methods research, such as quantitative surveys and qualitative interviews with students and faculty, to gather valuable data and insights.
- As BIM technology evolves, universities should continuously research its integration into academic programmes. Forming research groups within universities to study and report on the latest BIM applications will ensure that students are learning the most current and relevant technologies.
- Further research is required to evaluate the proposed BIMEXAE framework in practical settings. Academics can implement the framework in their courses and provide data for researchers to assess its effectiveness in achieving learning outcomes.

- Comparing different teaching methods for BIM integration is necessary. Designing experimental studies and collecting data on student outcomes will help determine the most effective approaches to teaching BIM.
- Developing a comprehensive BIM Body of Knowledge (BOK) specific to Libya is another important area of research. Conducting Delphi studies with experts and gathering input from industry professionals and educators will identify the essential knowledge, skills, and abilities for effective BIM use.
- Impact of BIM on education quality: longitudinal studies should investigate the impact of BIM integration on the overall quality of architectural education. Tracking student performance, job market success, and industry feedback will provide valuable insights into BIM's long-term effects on education quality and the AECO sectors.

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Annexes

Annex 1: Publications Related to BIM Adoption in the AECO sectors.

Table A1.1 to A1.3 annex collect publications reviewed at the initial stage of this research related to BIM in the construction industry, which is divided into three groups: (1) BIM awareness and adoption, (2) BIM training and resources in the construction industry and, (3) BIM benefits, Barriers and key drivers. This review helped provide a holistic background to the research and help to understand the current status of BIM implementation worldwide.

Table A1.1 BIM awareness and adoption.

No	Publication Titles	References
1.	BIM implementation for architectural practices	Arayici, 2011
2.	BIM-enabled facilities management	Becerik-Gerber et al., 2012
3.	International BIM implementation	RICS, 2014
4.	Global Strategies for BIM Implementation	Smith, 2014
5.	The current status and future trends of BIM	Bilal et al., 2016
6.	BIM awareness and adoption	NBS, 2016-2018
7.	Adoption of BIM in architectural design firms	Tulubas-Gokuc and Arditi, 2017
8.	BIM experiences and expectations: the constructors' perspective	Ku and Taiebat, 2011
9.	BIM shaping the future of construction	NFB, 2018
10.	Digital Transformation in Architecture	NBS Research, 2018
11.	Key factors of an initial BIM implementation	Kouch, 2018

Table A1.2. BIM training and resources in the construction industry.

No	Publications Titles	References
1.	BIM services and training	Silicon Valley, 2013
2.	BIM competencies requirements for specialists	Barison and Santos, 2011
3.	Training needs for BIM implementation in the construction industry	Pena, German, 2011
4.	BIM training in construction practice	Kolarić et al., 2018
5.	BIM education program for professionals	Lee and Hollar, 2013

Table A1.3. BIM benefits, Barriers, and key drivers.

No	Publications Titles	References
1.	BIM Trends, Benefits, Risks, and Challenges for the AECO Industry	Azhar, 2011
2.	The business value of BIM for construction in major global markets	McGraw Hill, 2014
3.	BIM adoption effects in the construction industry	Enegbuma et al., 2015
4.	Critical barriers to BIM Implementation in the AECO Industry	Liu et al., 2015
5.	Driving factors for implementing BIM	Saleh, 2015
6.	BIM benefits in architecture, engineering, and construction industry	Enshassi et al, 2018
7.	Benefits and challenges of BIM adoption in UK residential projects	Georgiadou, 2019
8.	Critical factors for the BIM adoption by architects	Ding et al., 2015

Annex 2: Publications Related to BIM Integration with Architectural Education.

Tables, A2.1 to A2.3 annex collect publications that discuss integrating BIM into education which used to understand the current status of BIM education; adoption, awareness, barriers, curriculum development, and the readiness of higher education to aching BIM, which provided the holistic background to the research and help to understand the current integration issues of teaching BIM.

Table A2.1. BIM awareness, importance, and responsibility.

No	Publications Titles	References
1.	Toward deep impacts of BIM on education	Turk and Starcic, 2019
2.	The importance of preparing architectural students on the use of BIM	Salman, 2013
3.	An initial investigation on BIM education for new career options	Wu and Issa, 2013
4.	Review BIM education and its future in undergraduate architectural	Aly, 2014
5.	Identify the current position and associated challenges of BIM Education	Underwood et al., 2015
6.	Review how universities are teaching BIM	Adamu and Thorpe, 2016
7.	BIM awareness and acceptance by architecture students	Ahn and Kim, 2016
8.	The responsible of Educating the next generation of architects for interdisciplinary BIM environments	Jaradat, 2016
9.	The AECO students' perspective on the learning process of BIM	Ozcan-Deniz, 2016
10.	Advances in BIM Education	Barison and Santos, 2018
11.	Implementation of BIM technologies in the educational program of the architectural university	Krivonogov et al., 2018
12.	CAD and BIM in architecture education: awareness, proficiency and advantages from the student perspective.	Maina, 2018
13.	Enhancing the graduates' employability and career development through BIM training	Ismail et al., 2019
14.	Global report on BIM Education progress	NATSPEC, 2017-2019

Table A2.2. Teaching and learning strategies for BIM education.

No	Publication Titles	References
1.	Identify current international trends in teaching BIM	Barison and Santos, 2011
2.	Review BIM education in practice	AIA-CA (2012)
3.	Developing a theoretical model for the introduction of BIM into the curriculum	Barison and Santos, 2012
4.	Implementation of BIM into accredited programs in architecture and construction education	Joannides et al., 2012
5.	The transformative effect of BIM on architectural curriculum	Morton, 2012
6.	Embedding BIM within the taught curriculum	BAF, 2013
7.	Devolving a tool for assisting teachers in planning BIM courses	Barison and Santos, 2014
8.	A competency knowledge base for BIM learning	Succar and Sher, 2014
9.	BIM curriculum development model	Faust, 2016
10.	Education of architects in the field of BIM technology	Jagiełło-Kowalczyk and Jamroży, 2016
11.	Planning and development of BIM curriculum for architectural education	Nawari and Alsaffar, 2016
12.	Provide different BIM education cases	Puolitaival et al., 2017
13.	A case study of BIM in the architecture curriculum	Abdelhameed, 2018

Table A2.3. BIM education readiness and challenges.

No	Publication Titles	References
1.	Identify challenges of integrating BIM in architectural education	Kocaturk and Kiviniemi, 2013
2.	A Curriculum Approach to Deploying BIM in Architectural Engineering	Solnosky and Parfitt, 2015
3.	BIM curriculum design in architecture, engineering, and construction education	Abdirad and Dossick, 2016
4.	BIM education-the current and future approach by universities	Kiviniemi, 2016
5.	Identify the practical challenges of BIM education	Puolitaival and Forsythe, 2016
6.	Dynamic Representation of Barriers to Adopting BIM	Belayutham, Zabidin and Che Ibrahim, 2018
7.	A Review of challenges of BIM education	Huang, 2018
8.	Evaluate academic readiness for BIM Integration into higher education institutions.	Yusuf, Embi and Ali, 2017

Annex 3: Survey A for Professionals

Questionnaire A for Professionals aims to develop a theoretical framework for BIM excellence in education. It was designed to collect relevant data for BIMEXAE framework development. The survey was conducted in Year 2, and there are 174 survey participants. Details about data collection and analysis are described in Chapter 5.

A3.1 Cover Letter.

University of Strathclyde Glasgow

Dear Sir/Madam,

BIM Excellence in Architectural Education in Libya

I am a PhD candidate at the University of Strathclyde. As part of my research, you are kindly invited to participate in a research study titled "*BIM Excellence in Architectural Education in Libya*". This research aims to develop a theoretical framework for excellence in Building Information Modelling (BIM) education. This framework has the potential to help academics, policymakers, and practitioners facilitate the incorporation of BIM education within architectural programmes at Libyan universities.

Please do not hesitate to contact me for more information and any concerns. Thank you for your participation.

Kind regards,

Ozaer Zaed
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A3.2 Survey A with Professionals

Questionnaire A for Professionals aims to develop a theoretical framework for BIM excellence in education. It was designed to collect relevant data for BIMEXAE framework development. The survey was conducted in Year 2 and there are 174 survey participants. Details about data collection and analysis are described in Chapter 5.

Part 1: General Information

Q1. What is your age?

- ☐ 18 - 23
- ☐ 24 - 35
- ☐ 36 50
- ☐ 51 or above

Q2. How many years of experience do you have in the construction industry?

- ☐ 1-4
- ☐ 5-10
- ☐ 11-20
- ☐ 21-30
- ☐ More than 30

Q3. What is your academic qualification?

- ☐ Diploma
- ☐ Bachelor
- ☐ Master
- ☐ PhD
- ☐ Other

Q4. What is your main occupation?

- ☐ Architect
- ☐ Engineer/Civil Engineer
- ☐ Project Manager
- ☐ Consultant/Adviser
- ☐ Contractor
- ☐ Client
- ☐ Others

Q5. What type of sector do/did you work with?

- ☐ Public (government)

- ◻ Private
- ◻ Both

Part 2: Organisation Activities:

Q6. Which type of construction related to operation best describes your organisation?

- ◻ Architectural practice
- ◻ Urban development
- ◻ Construction Company
- ◻ Office consultant
- ◻ Others

Q7. Which size of projects does your organisation deliver?

- ◻ Small
- ◻ Medium
- ◻ Large

Q8. Including yourself, how many employees work in your organisation?

- ◻ 1-5
- ◻ 6-15
- ◻ 16- 30
- ◻ 31-50
- ◻ 51-100
- ◻ 100-500
- ◻ More than 500

Part 3: The Use of Digital Technologies

Q9. Which of the following application are you using to deliver projects?

- ◻ Sketchup
- ◻ ArchiCAD
- ◻ Autodesk AutoCAD
- ◻ Autodesk Ecotect
- ◻ Graphisoft ArchiCAD
- ◻ Autodesk Revit (Architecture/Structures/MEP)
- ◻ Other (please specify)

Q10. Which of the following statements apply to you personally?

- ☐ I produce hand drawings
- ☐ I produce 2D digital drawings that are not generated from a 3D model
- ☐ I use structured information that is linked to 3D digital models
- ☐ I produce 3D digital models
- ☐ I produce Building Information Model (BIM) objects
- ☐ None of these

Part 4: Awareness and Adoption of BIM

Q11. To what extent are you aware of BIM?

- ☐ Unaware
- ☐ Little awareness
- ☐ Moderately aware
- ☐ Very aware
- ☐ Extremely aware

Q12. How did you get BIM knowledge?

- ☐ Self-learning
- ☐ Seminars/ conferences/workshops
- ☐ Professional training courses
- ☐ BIM graduate
- ☐ Other

Q13. Does the organisation where you are working now is applying BIM?

- ☐ Yes
- ☐ No
- ☐ I do not know

Q 13.1. If yes, how does your organisation implement BIM?

- ☐ In house
- ☐ partial in-house/outsourcing
- ☐ full outsourcing
- ☐ I do not know

Q13.2. If not, do you know when your organisation will be starting the adoption of BIM?

- □ In the near future
- □ Is not in the near future
- □ I do not know

Q 14. How important do you think BIM is to the AECO industry?

- □ Extremely important
- □ Very important
- □ Moderately important
- □ Slightly important
- □ Not at all important

Part 5: Training and Resources for BIM

Q15. In your organization, is there BIM training?

- □ Yes
- □ No

Q16. In your opinion, does your organisation need professionals specialised in BIM?

- □ Yes
- □ No
- □ I do not know

Q17. Which of the following is best for employees to learn BIM? (You may choose more than one option).

- □ Self-learning
- □ Seminar/ Workshop/ Conferences
- □ Training sessions in the company
- □ universality courses
- □ Academic learning (hiring skilled/ experienced personnel)

Part 6: Barriers and Key Drivers of BIM Adoption

Q18. What are the main barriers to adopting BIM in your organisation?

- □ Lack of awareness
- □ Lack of resources
- □ Lack demanded
- □ High investment; (software, hardware, & training)
- □ lack of a skilled workforce

- ☐ lack of government support
- ☐ Lack of collaborative process
- ☐ lack of any standardised approach
- ☐ Culture resistance

Q19. How strongly do you agree or disagree with the following statements about key drivers for BIM adoption in the construction industry?

- ☐ Government should mandate/support BIM
- ☐ Availability of standardised approach
- ☐ Availability of BIM resources
- ☐ Providing appropriate training
- ☐ Availability of adequate research that covers all BIM aspects
- ☐ Universities should lead the adoption and promotion of BIM.
- ☐ Universities should provide graduates that have BIM knowledge and skills.

Part 7: BIM Integration with Architectural Education

Q20. How important is it for architectural education programs to integrate BIM concepts and tools?

- ☐ Extremely important
- ☐ Very important
- ☐ Moderately important
- ☐ Slightly important
- ☐ Not at all important

Q21. What is the most crucial aspect to focus on when teaching BIM within universities?

- ☐ BIM theory
- ☐ BIM practice (software)
- ☐ Both

Q22. Do you believe that a curriculum design and development approach is essential for effective BIM education in architectural programs?

- ◻ Yes
- ◻ No
- ◻ I am not sure

Q23. Should universities prioritise developing partnerships with industry stakeholders to enhance BIM education opportunities for students?

- ◻ Strongly disagree
- ◻ Disagree
- ◻ Neutral
- ◻ Agree
- ◻ Strongly agree

Annex 4: Survey B for Academics

Questionnaire B for Academics aims to develop a theoretical framework for BIM excellence in education. It was designed to collect relevant data for BIMEXAE framework development. The survey was conducted in Year 2 and there are 225 survey participants. Details about data collection and analysis are described in Chapter 6.

A4.1 Cover Letter.

Dear Sir/Madam,

BIM Excellence in Architectural Education

I am a PhD candidate at the University of Strathclyde. As part of my research, you are kindly invited to participate in a study titled "*BIM Excellence in Architectural Education*". This research aims to develop a theoretical framework for excellence in Building Information Modelling (BIM) education. This framework has the potential to help academics, policymakers, and practitioners facilitate the incorporation of BIM education within architectural programmes at Libyan universities.

Please do not hesitate to contact me for more information and/or any concerns. Thank you for your participation.

Kind regards,

Ozaer Zaed
PhD Candidate
Department of Architecture
Faculty of Engineering
University of Strathclyde
Glasgow, G1 1XJ, UK
Email: Ozaer.zaed@strath.ac.uk

A4.2 Survey B with academics

Part 1: General information

Q1. Please select your age

- ☐ 18 - 23
- ☐ 24 - 35
- ☐ 36 - 50
- ☐ 51 or older

Q2. How long have you been teaching in higher education?

- ☐ 1 - 4
- ☐ 5 - 10
- ☐ 11 - 15
- ☐ 16 - 20
- ☐ 21 - 30
- ☐ More than 30

Q3 What is your academic qualification.

- ☐ Diploma
- ☐ Bachelor
- ☐ Master
- ☐ Ph.D.
- ☐ Other

Q4. What is your current academic position?

- ☐ Professor
- ☐ Teaching Assistant
- ☐ Assistant professor
- ☐ Associate Professor
- ☐ Others

Q5. Which University do/did you work at?

……………………………………………………………………………………………

Q6. Which Department/s do/did you work at?

- ◻ Architecture
- ◻ Civil engineering
- ◻ Construction management
- ◻ Other

Part 2: The use of digital technologies

Q7. Which of the following tools are taught in the architectural programme?

- ◻ Sketchup
- ◻ Autodesk AutoCAD
- ◻ Autodesk Ecotect
- ◻ ArchiCAD
- ◻ Graphisoft ArchiCAD
- ◻ Autodesk Revit (Architecture/Structures/MEP)
- ◻ Other (please specify)

Q8. What is the main purpose of teaching tools in the architectural programme?

- ◻ To produce 2D digital drawings that are not generated from a 3D model
- ◻ To use structured information that is linked to 3D digital models
- ◻ To produce 3D digital models
- ◻ To create schedules from models
- ◻ To produce Building Information Model (BIM) objects
- ◻ None of these

Part 3: BIM awareness, importance, and responsibility

Q9. To what extent are you aware of BIM?

- ◻ Unaware
- ◻ Little awareness
- ◻ Moderately aware
- ◻ Very aware
- ◻ Extremely aware

Q10. How did you get BIM knowledge?

- ◻ Self-learning
- ◻ Seminars/ conferences/workshops
- ◻ Professional training courses
- ◻ BIM graduate

- ☐ Other

Q11. In your department, do you teach on BIM?

- ☐ Yes
- ☐ No
- ☐ I do not know

Q11.1. If yes, how BIM has been taught in your department?

- ☐ 3D modelling software
- ☐ Standalone course
- ☐ Integrated with design studio
- ☐ Integrated with existing module
- ☐ Seminars
- ☐ Online courses
- ☐ In some themes

Q11.2 If no, do you think your department will have a module or course on BIM?

- ☐ Rare
- ☐ Unlikely
- ☐ Possible
- ☐ likely
- ☐ Most likely

Q12. How relevant do you think BIM is to architectural education?

- ☐ Not relevant
- ☐ Little relevant
- ☐ Somehow relevant
- ☐ Relevant
- ☐ Very relevant

Q13. How important do you think BIM is to be integrated with architectural education in Libya?

- ☐ Not important
- ☐ Little important
- ☐ Somehow important
- ☐ Important
- ☐ Very important

Q14. What is the influence of government and professional bodies in the construction industry in delivering BIM education?

- □ Not Influence
- □ Little influence
- □ Somehow influence
- □ Influence
- □ Very influence

Q15. How strongly do you agree or disagree with the following statements about the importance and responsibility of BIM education?

- □ Could BIM education be applied to meet the demands of BIM teachers and trainers?
- □ Could BIM education be applied to meet the demands of today's professionals?
- □ Could BIM education be applied to meet the demands of future professionals?
- □ Is BIM education a shared educational responsibility between government, industry and academia?

Part 4: Teaching and learning strategies for BIM education.

Q16. To teach BIM, would you need to make adjustments in your programmes or department?

- □ Yes
- □ No
- □ I don't know.

If yes, what would you need to change?

Q 17. To implement changes in this discipline(s) would you need (or need) some assistance?

- □ Yes
- □ No
- □ I don't know
- □ If yes, what kind of assistance would be?

…………………………………………………………………………………………….

Q18. What type of courses should BIM be taught as an undergraduate architectural programme?

- □ Elective course
- □ Core course

- ☐ External course
- ☐ Other

Q19. In your opinion, which is the right year for the undergraduate architectural programme to introduce BIM to students?
You may choose more than one option

- ☐ Preparation year
- ☐ First year
- ☐ Second year
- ☐ Third year
- ☐ Fourth year
- ☐ I don't know

Why? …………………………………………………………………………………………

Q20. What are the most preferable strategies to successfully incorporate BIM education within architectural education? Please indicate your level of preference.

- ☐ BIM standalone courses
- ☐ BIM integrates with existing courses
- ☐ BIM integrated with design studio
- ☐ BIM used in graduation projects
- ☐ BIM collaboration course in the same discipline
- ☐ BIM collaboration course with other disciplines
- ☐ BIM collaboration course with other universities
- ☐ Combine BIM teaching with online videos.
- ☐ Restructure the current curriculum to integrate BIM.
- ☐ Seminars, workshops, or conference
- ☐ BIM-focused degree program

Part 5: BIM Education Readiness and Challenges

Q21. Do you think your university is ready to integrate BIM within its programmes?

- ☐ Yes
- ☐ No
- ☐ if no, please explain why.

Q22. In your opinion, can you evaluate the level of maturity or readiness of BIM education in your university based on identified criteria?

Criteria	Maturity level					
	Level 0 Non-existent	**Level 1 Initial**	**Level 2 Defined**	**Level 3 Managed**	**Level 4 Integrated**	**Level 5 optimizing**
University vision						
Software						
Hardware						
Facilities						
Curriculum design and development						
Professional development						
Teaching and learning resource						

Q23. What do you think are the possible challenges would face (or faced) to introducing BIM into the curriculum? Please indicate your level of agreement.

- □ Lack of awareness
- □ Lack of experienced lecturers in BIM.
- □ Reluctance for changing curriculum.
- □ Lack of qualified staff to teach BIM.
- □ Lack of staff interested in teaching BIM.
- □ Lack of students interested in learning BIM.
- □ No room available for a new course
- □ Longer time is needed to learn BIM software.
- □ Longer time is needed to restructure curricula.
- □ No accreditation standards.
- □ Insufficient funding source to train staff.
- □ Lack of support from the government
- □ Lack of academic and professional collaboration.
- □ Limit access to software for students.
- □ Rapidly evolving technology.
- □ Lack of good computers and proper equipment

Annex 5: Survey C for Framework Assessment

This Questionnaire aims to validate the developed framework for BIM excellence in education. It was designed to evaluate the components, value, design, applicability, suitability, and effectiveness of the developed framework using a questionnaire-based survey with Libyan educators. The survey was conducted in Year 4, and there are 27 survey participants. Details about data collection and analysis are described in Chapter 8.

A5.1 Cover Letter

Dear Sir/Madam,

BIM Excellence in Architectural Education in Libya

I am a PhD candidate at the University of Strathclyde. As part of my research, you are kindly invited to participate in the assessment process in a research study titled "*A framework for BIM Excellence in Architectural Education in Libya*". This survey aims to validate the framework developed from this study. This framework has the potential to help academics, policymakers, and practitioners facilitate the incorporation of BIM education within architectural programmes at Libyan universities.

Please do not hesitate to contact me for more information and any concerns. Thank you for your participation.

Kind regards,

Ozaer Zaed
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Faculty of Engineering
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Glasgow, G1 1XJ, UK
Email: Ozaer.zaed@strath.ac.uk

A5.2 Survey C

Part 1: General Information

Q1. How long have you been teaching in higher education?

- ☐ 1 – 4
- ☐ 5 - 10
- ☐ 11 - 15
- ☐ 16 - 20
- ☐ 21 – 30
- ☐ More than 30

Q2. What is your academic qualification?

- ☐ Diploma
- ☐ Bachelor
- ☐ Master
- ☐ PhD
- ☐ Other

Q3. What is your current academic position?

- ☐ Assistant Professor or Lecturer
- ☐ Associate Professor or Senior Lecturer
- ☐ Professor
- ☐ Teaching Assistant
- ☐ Others

Q4. Which University do/did you work at?

Please mention:

……………………………………………………………………………………………

Q5. Which Department/s do/did you work at?

- ☐ Architecture
- ☐ Civil Engineering
- ☐ Construction Management
- ☐ Other

Q6. To what extent are you aware of BIM?

☐ Unaware
☐ Little awareness
☐ Moderately aware
☐ Very aware
☐ Extremely aware

Part 2: Questions Related to the Framework

Q7. Is the framework easy to understand and use?

☐ Yes
☐ No
☐ Please add your comment/observation:

Q8. Are the framework components well-defined?

☐ Yes
☐ No
☐ Please add your comment/observation:

Q9. Is the framework well designed?

☐ Yes
☐ No

Q10. Does the framework represent *Strategical requirements on BIM integration?*

☐ Yes
☐ No

Q11. Does the framework demonstrate an effective procedure to integrate BIM into an educational program?

☐ Yes
☐ No

Q12. Is this framework suitable for Architectural education in Libya?

☐ Yes
☐ No

Q13. What are your suggestions for this framework to be improved for architectural education in Libya.

Annex 6: The Periodic Table of BIM in Education

This appendix analyses NBS The Periodic Table of BIM (NBS, 2016), specifically focusing on its implications for BIM education. Table A6.1 serves as a guide for educators, students, and professionals, aiming to bridge the gap between theoretical understanding and practical application of BIM. By integrating these BIM principles into architectural curricula and workflows, which can allow the architectural and construction workforce with the necessary skills and knowledge for success in the digital age.

Table A6.1. The Periodic Table of BIM in Education

Main Elements	Sub Elements	BIM Education Consideration
Strategy	BIM Strategy	Define the strategic goals of BIM adoption in architectural education.
Foundations	Framework	Develop a structured framework for progressively building BIM skills throughout the curriculum
	Common methods	Integrate common BIM methods and practices relevant to architectural workflows
	Procurement route	Familiarise students with procurement routes incorporating BIM in architectural projects
	Capability and capacity	Address the development of skills and capacity for effective BIM implementation
Collaboration	Culture and behaviour	Emphasize collaborative skills and foster a BIM-friendly culture in architectural practice
	Process	Educate how integrate collaborative BIM processes in design and project delivery
	Forms of procurement	Include knowledge on different forms of BIM-friendly procurement in architectural projects
	Digital tools	Train students in using digital collaboration tools essential for BIM projects
	Standardisation and Interoperability	Incorporate understanding of BIM standards and interoperability in collaborative workflows
Process	Assessment and need	Teach students to assess BIM needs at various stages of architectural projects
	Execution	Provide skills for executing BIM processes effectively in architectural design
	Delivery	Educate on the delivery of BIM models and information in architectural projects
	Maintenance and use	Include knowledge on the ongoing maintenance and use of BIM in the building lifecycle
	Digital Plan of Work	Train students in creating and implementing a Digital Plan of Work for architectural projects
	Employers’ info requirements	Familiarize students with fulfilling employers' information requirements in BIM projects
	BIM execution plan	Teach the creation and utilization of BIM Execution Plans in architectural projects
	Master information delivery plan	Emphasize the importance of Master Information Delivery Plans in architectural BIM

Main Elements	Sub Elements	BIM Education Consideration
	Common data Environment	Introduce the concept and utilization of a Common Data Environment in BIM projects
	Information exchange	Train on effective information exchange protocols in architectural BIM projects
People	Communication	Enhance communication skills for effective collaboration in BIM-based architectural projects
	Soft skills	Develop soft skills to support teamwork, client interaction, and project leadership
	Cooperation	Emphasize the importance of cooperation and interdisciplinary collaboration in BIM
	Champion	Educate on the role of BIM champions in driving BIM adoption in architectural practice
	Support	Provide knowledge on support structures and mechanisms in BIM-based architectural projects
	Investment	Address the need for investment in technology and training for successful BIM implementation
	Change process	Train students to manage and navigate through change processes associated with BIM
	Share success	Encourage the sharing of successful BIM implementation stories and case studies
	Availability	Ensure access to resources and technology for continuous learning and practice
	Engage	Promote active engagement with BIM communities, events, and industry stakeholders
Technology	Software	Provide hands-on training on various BIM software applications used in architectural design
	Hardware	Educate on the hardware requirements and considerations for BIM in architectural projects
	Training	Include comprehensive training on tools supporting BIM processes in architectural practice
	File storage	Emphasize effective file storage and management practices for architectural BIM projects
	Infrastructure	Address the essential infrastructure required for successful BIM implementation in architecture
Standards	Capital delivery phase	Introduce and incorporate national and international BIM standards relevant to architectural projects
	Operational phase	Integrate education on quality management systems throughout the operational phase of projects
	Facilities management	Familiarize students with BIM in facilities management and its role in the operational phase
	Digital security	Include knowledge on digital security considerations in handling BIM data
	Briefing	Train on creating and understanding BIM briefs for architectural projects
	Collaborative business relationships	Educate on establishing and maintaining collaborative business relationships in BIM

Main Elements	Sub Elements	BIM Education Consideration
	Protocol	Include education on BIM protocols and guidelines relevant to architectural projects
	Quality management systems	Integrate education on quality management systems in architectural BIM
	Design Management Systems	Provide knowledge on design management systems in architectural BIM projects
	Asset management	Introduce the role of BIM in asset management and its relevance in architectural projects
	Library objects	Educate on creating, managing, and utilizing BIM library objects in architectural design
	Prequalification questionnaires	Train on using BIM in prequalification processes for architectural projects
	buildingSMART data dictionary	Promote understanding and use of buildingSMART data dictionary in architectural BIM
	Industry foundation classes	Provide training on using Industry Foundation Classes (IFC) in architectural BIM
	Information delivery manual	Educate on creating and utilizing Information Delivery Manuals in architectural projects
Enabling Tools	BIM Toolkit	Train on the application and use of the BIM Toolkit in architectural practice
	Level of detail	Educate on the importance and implementation of classification systems in architectural BIM
	Classification	Offer training on tools used in creating and managing BIM content classification
	Computer-Aided Facilities Management	Introduce the use of BIM in Facilities Management for architectural projects
	Programme tools	Train on tools facilitating program management in architectural BIM
	Authoring tools	Educate on authoring tools for BIM content creation in architectural projects
	Specification tools	Train on tools used for specifying BIM content in architectural design
	Level of Information	Provide knowledge on specifying the appropriate level of information in architectural BIM
	Analysis tools	Educate on tools for analyzing BIM data in architectural projects
	Cost tools	Train on tools for managing costs in architectural BIM projects
	Administration tools	Provide training on administrative tools for architectural BIM projects
	Model viewers and checkers	Educate on tools for viewing, checking, and collaborating on BIM models in architecture
	File sharing and collaboration	Train on effective file sharing and collaboration tools for architectural BIM
Resources	Surveys and Reports	Encourage students to explore and analyze BIM surveys and reports relevant to architecture

Main Elements	Sub Elements	BIM Education Consideration
	Videos	Promote the use of videos for learning and staying updated on BIM practices in architecture
	Events	Encourage participation in BIM events, conferences, and seminars related to architecture
	Forums and user groups	Foster engagement in BIM forums and user groups for architectural education
	Social media	Leverage social media for sharing resources and insights on architectural BIM
	Blog posts	Promote writing and reading blog posts on various aspects of BIM in architecture
	Books	Recommend relevant books covering a range of BIM topics in architectural practice
Digital Plan of Work	Strategy	Train on creating and implementing a Digital Plan of Work for architectural projects
	Brief	Educate on creating comprehensive BIM briefs for architectural projects
	Definition	Introduce the process of defining BIM requirements and scope in architectural projects
	Design	Provide knowledge on utilizing BIM in architectural design phases
	Build and commission	Train on BIM processes during the construction and commissioning phases in architecture
	Handover and closeout	Educate on the BIM aspects of project handover and closeout in architectural practice
	Operation	Introduce the role of BIM in the operational phase of architectural projects

Annex 7: A Review of Educational Framework

This annex summarises the literature review of academic publications on positive practices in BIM education integration. A brief summary from the literature review on the relevant criteria identified for the framework is provided in Tables A7.1 to A7.3, and these include A review of a general education framework summarised in Table A7.1, A review of an architectural education framework summarised in Table A7.2, and A review of BIM integrated education framework summarised in Table A7.3.

Table A7.1. A review of the general education framework

Dimensions	Criteria for Framework Development	Reflections in Representative References		
		Blended Learning and Teaching (Lim et al., 2019; Zaugg et al., 2021)	*The Higher Education Digital Capability (HEDC) Framework* (HolonIQ, 2021)	*Integrating Higher Education Planning and Assessment* (Hollowell et al., 2010)
Professional Development	Professional competence and development	Professional development	Subject matter expertise	Human resources
			Academic administration	
	Academic and professional collaborations	Partnerships	Student recruitment	
			Alumni and continuing education	
Education Product	Convergence of educational strategy, tactics and operation	Vision and policy alignment	Product strategy	Academic support services
			Teaching strategies	Investment strategies
	Inclusive curriculum design and development	Curriculum	Curriculum design	Instructional curriculum
			Digital content and courseware	
Education Process	Educational infrastructure and resources management	Infrastructure, facilities, resources, hardware, and support	Environment	Budget planning
			Industry and business engagement	New construction
				Facilities renewal/renovation
				Technology infrastructure
	Education process enhancement	Research and evaluation Student learning support	Assessment and verification	Residence life
			Marketing processes	Student support services
			Student life	
			Academic experience	

Table 7.2. Review of architectural education framework

Dimensions	**Criteria for Framework Development**	**Reflections in Representative References**		
		Holistic sustainable architectural education framework (Shari and Jaafar, 2006)	*Architectural framework for higher education (Nama et al., 2018)*	*Criteria for architectural education knowledge framework (ARB, 2021)*
Professional development	Professional competence and development		Business architecture	Professional requirements
				Professional regulation
				Professionalism
	Academic and professional collaborations	Research requirements		Practice management
Education Product	Convergence of educational strategy, tactics and operation	Education program	Architectural vision	Theories and practice of architecture
				Architectural design requirements
	Inclusive curriculum design and development	Curriculum review	Architectural framework and principles	Curriculum development
Education Process	Educational infrastructure and resources management		Information systems architectures	
			Technology architectural	
	Education process enhancement	Regulatory requirements	Opportunities and solutions	Socio-cultural Principles
		Publicity requirements		Student employability
				Design skills

Table 7.3. Review of BIM integrated education framework

Dimensions	**Criteria for Framework Development**	**Reflections in Representative References**		
		Planning a BIM curriculum framework (Barison and Santos, 2010)	*BIM maturity framework for higher education institutions (Böes et al., 2021)*	*BIM adoption framework for architectural education (Maharika et al., 2020)*
Professional development	Professional competence and development		Faculty training	Human resources
	Academic and professional collaborations		Faculty BIM engagement	
Education Product	Convergence of educational strategy, tactics and operation	Prerequisites	BIM Institutional View	Institution vision and priorities
		Goals and Objectives	BIM disciplines	
	Inclusive curriculum design and development	Contents	BIM teaching	Curriculum integration
		Activities		Knowledge organization
Education Process	Educational infrastructure and resources management	BIM Models	Infrastructure, hardware, and software development	Infrastructure
		Teaching resources		
	Education process enhancement	Teaching Methodologies	Publications	Change management
		Evaluation	Academic extension	
			Student training	

Annex 8: BIM Educational Programme Maturity Matrix

This annex summarises the BIM Educational Programme Maturity Matrix that the university can use to identify the level of BIM education. Table A8.1 to A8.3 describes three dimensions of BIM programme maturity matrix: D1 Education Product, D2 Professional development and, D3 Education process. These dimensions include the main criteria identified and adopted in the research into developing a BIM-integrated education framework. The criteria were identified as significant pathways resulting from the literature review and addressed the authors' experiences in higher education in related subject areas.

Table A8.1. Assessing BIM Education product

Criteria	Maturity Levels				
	Level 0 **Non-Existent**	**Level 1** **Initial**	**Level 2** **Defined**	**Level 3** **Managed and Integrated**	**Level 4** **Optimizing**
University vision and mission	BIM is not included in university planning.	BIM is not included in university planning. However, there is no internal hindrance to education initiatives.	BIM is included in the university plan but not classified as a priority in teaching methodology.	BIM is viewed as a priority and essential aspect of university planning. However, there is no official of this university's view	BIM is viewed as a priority method in the university's vision. BIM is integrated with core courses.
Curriculum design and development	BIM is not included in the curriculum. No BIM curriculum was developed.	No BIM curriculum was developed. However, BIM concepts and benefits are introduced to students.	Developing and creating new courses/modules related to BIM.	Developing existing modules to integrate BIM.	Developed BIM inclusive curriculum and BIM integrated with core architectural courses and related courses

Table A8.2. Assessing the professional development of BIM education

Criteria	Maturity levels				
	Level 0 Non-Existent	**Level 1 Initial**	**Level 2 Defined**	**Level 3 Managed and Integrated**	**Level 4 Optimizing**
Professional competence and development	There is no program to train faculty on BIM.	University encourages staff to have training on BIM	Developing a program to train and educate staff.	Provide periodic training for BIM education purposes.	BIM is required in the matrix of competence for hiring educators
Academic and professional collaborations	There is no collaboration between academics and professionals	There is no formal collaboration. However, there is individual cooperation between staff in the department.	Create formal relationships between academics and professionals.	Professionals assist in developing the BIM curriculum and providing practical staff training.	Professionals provide a presentation of real BIM case studies to students. Collaboration between academics to reduce the repetition and duplication of teaching resources.

Table A8.3. Assessing BIM education process

Criteria	Maturity levels				
	Level 0 **Non-Existent**	**Level 1** **Initial**	**Level 2** **Defined**	**Level 3** **Managed and Integrated**	**Level 4** **Optimizing**
Teaching resource	There is no teaching resource available for staff or students.	Staff prepare initial teaching materials	Staff prepare different BIM teaching materials (tutorials and lectures)	BIM teaching materials are available for staff and students	University develops an online database including teaching materials and prototypes of BIM projects.
Software, hardware	There is no installed software or proper hardware.	Make agreements with software and hardware developer	Installing main BIM software and providing some proper hardware in the computing lab.	Installing more BIM software and providing licenses for staff and students. Provide proper hardware in all computing labs	BIM software is installed in all computing labs with continued improvement for software and hardware based on the BIM education plan.
Teaching space	There is no physical space for teaching BIM.	Provide initial teaching space, for example, sharing a computing lab with other uses	Creating suitable BIM teaching space	BIM teaching spaces with customized hardware and facilities. Space with infrastructure for interactivity and information sharing.	BIM teaching space with an active and collaborative learning environment and high student engagement.
Research and publication	There is no research or publication.	Preliminary BIM research inside the university.	Organize seminars and workshops related to BIM.	Organize a national conference on BIM and encourage staff and students to present research.	Organize an international conference on BIM. Published papers on BIM education and practice.

Annex 9: Initial BIM Programme Framework Development

This annex defines the initial framework for a BIM Programme. It outlines a strategic approach for developing and implementing BIM throughout a project lifecycle, focusing on three key work stages (See **Table A9.1**)

Table A9.1. Initial BIM Programme Framework

Domains of evaluation criteria	Work stages of BIM-integrated education development		
	1. Programme preparation	**2. Programme deployment**	**3. Programme improvement**
A. University vision	1.1. Identifying the purpose of BIM education	2.1. Deploying a BIM education programme in accordance with the university's implementation plan	3.1. Teaching BIM as a methodology in teaching and learning activities
B. Infrastructure development (software, hardware, and facilities)	1.2. Diagnosing current educational infrastructure 1.3. Proposing a plan for enhancing the existing educational infrastructure (software and equipment)	2.2. Installing main BIM software and providing licences for staff and students	3.2. Installing different software in all BIM teaching spaces
		2.3. Providing suitable hardware to use BIM in the university	3.3. Providing proper hardware with BIM use, with plans to develop a continuous improvement programme
		2.4. Creating suitable spaces for teaching and learning BIM	3.4. Teaching BIM in a collaborative learning environment with student engagement from different disciplines
C. Professional competence and development	1.4. Developing a plan to promote BIM learning in the faculty 1.5. Staff training	2.5. Periodic training according to the BIM implementation plan	3.5. BIM requirements in the competency matrix for teacher recruitment
D. Curriculum design and development	1.6. Developing and creating new courses/modules related to BIM	2.6. Developing existing modules to integrate BIM	3.6. Integrating BIM with the core architectural courses and related disciplines
E. Academic and professional collaborations	1.7. Creating relationships between academics and professionals	2.7. Professional assistance in developing BIM courses and providing practical training for teachers on BIM tools	3.7. Professional presentations of real BIM case studies to students
F. Education process enhancement	1.8. Providing improvements to the educational process through publications, evaluation, and even students' perceptions		

Annex 10: Publications

To effectively disseminate research findings and foster scholarly dialogue, the researcher actively engaged in presenting research outcomes at both national and international conferences. This strategic approach facilitated the sharing of key research insights with a broader academic community. Moreover, constructive feedback garnered from these presentations served as a catalyst for refining and enhancing the research trajectory.

The publications detailed in this annex summarise the core findings of the research. They represent a collection of the study's key outcomes and contributions to the field.

Zaed, O. and Chen, Z. (2019) ‘A methodological approach to excellence in BIM oriented architectural education’, *in Doctoral Workshop on Contemporary Advances in Research Methodology in Construction Management Workshop conveners: Glasgow Caledonian University, Glasgow, UK*, pp. 1–3.

Zaed, O. and Chen, Z. (2021) ‘Developing excellent architectural education for best practices in Libya’, *Journal of Pure and Applied Sciences*, 20(3), pp. 1–5. Available at: https://doi.org/10.51984/jopas.v20i3.999.

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