buildings

MDPI

Review

Integrating Building Information Modelling into Construction Project Management Education in Australia: A Comprehensive Review of Industry Needs and Academic Gaps

Xavier Papuraj, Nima Izadyar * and Zora Vrcelj *

Institute for Sustainable Industries and Liveable Cities, Victoria University, P.O. Box 14428, Melbourne, VIC 8001, Australia; xavier.papuraj@live.vu.edu.au

* Correspondence: nima.izadyar@vu.edu.au (N.I.); zora.vrcelj@vu.edu.au (Z.V.)

Abstract: Integrating Building Information Modelling (BIM) into Construction Project Management (CPM) curricula is crucial for preparing industry-ready professionals with the digital competencies needed in the rapidly evolving, technology-driven construction sector. This systematic literature review evaluated gaps and challenges in BIM education within CPM courses, including limited faculty training, inconsistent curricula, and insufficient hands-on, interdisciplinary collaboration opportunities for students. These deficiencies hinder consistent BIM competency development among graduates, resulting in disparities in skill levels and readiness for industry demands. This study identified essential digital management skills and BIM competencies required for effective industry practice by examining global academic research. The findings revealed that despite advancing BIM adoption, significant gaps persist in its teaching, particularly the lack of collaborative education within project management disciplines, and need for enhanced collaboration between academia and the industry to bridge the skills gap. Industry professionals and academics emphasise the deficit in BIM knowledge among project management graduates and advocate for a cohesive educational framework aligning with industry requirements, emphasising hands-on experience and interdisciplinary collaboration. This study highlighted significant gaps and opportunities for integrating Building Information Modelling (BIM) into Construction Project Management (CPM) education, with the aim to enhance the competency and employability of future construction project managers. By proposing a phased approach and a BIM educational framework tailored to the Australian context, this review recommended the integration of BIM, supported by other emerging technologies, to better align educational outcomes with industry demands. The recommendations focus on curriculum design and implementation strategies to bridge the identified gaps.

Keywords: Australian higher education; Building Information Modelling (BIM) competencies; BIM education; Construction Project Management (CPM); curriculum development; industry–academic collaboration

check for updates

Academic Editor: Wenzhe Tang

Received: 15 November 2024
Revised: 5 December 2024
Accepted: 31 December 2024
Published: 3 January 2025

Citation: Papuraj, X.; Izadyar, N.; Vrcelj, Z. Integrating Building Information Modelling into Construction Project Management Education in Australia: A Comprehensive Review of Industry Needs and Academic Gaps. *Buildings* **2025**, *15*, 130. https://doi.org/10.3390/buildings15010130

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

The construction industry is transforming through Construction 4.0 as it shifts the focus of the practitioners to embrace technology-driven processes influenced by numerous technologies representing within the scope of Construction 4.0, including Building Information Modelling (BIM), artificial intelligence (AI), laser scanning, 3D printing, robotics, and virtual, mixed, and augmented reality (VR, MR, and AR) [1–3]. It is geared towards automation, data-driven technologies, and advanced artificial intelligence (AI) techniques.

The subfields of AI such as machine learning, natural language processing, robotics, computer vision, optimisation, automated planning, and scheduling [4], were applied to tackle complex issues, and support decision-making for real world problems [5]. This led to significant process improvements, cost-efficiency, improved safety, and helped to achieve sustainability goals. This transformation fundamentally changes planning, design, construction, and operational aspects within the Architecture, Engineering, Construction, and Operations (AECO) Industry [6–8]. Construction 4.0 demands a paradigm shift in design and construction methodologies, emphasising the need to prepare a workforce skilled in digital and collaborative practices [8]; as such, the impact is much larger than its component-level technological advancements.

1.1. Research Background

Building Information Modelling (BIM), as an ecosystem of robust technologies and streamlined processes, plays a pivotal role in the AECO industry as it enables a collaborative mechanism with the project team members to virtually represent information required for planning, design, construction, and operation tasks, from early inception stages of projects throughout the life-cycle phases of the facility [9]. BIM offers specific industry benefits, including enhanced collaboration, project cost savings, and improved lifecycle efficiency. By reducing errors through early-stage virtual modelling and fostering interdisciplinary communication, BIM improves overall project efficiency and accuracy across building phases. Recent advancements in AI technologies, such as predictive analytics and generative design, enabled new applications of BIM in Construction Project Management (CPM). For instance, the study by [4] demonstrated how AI-driven BIM models optimise construction schedules and cost estimates, reducing delays and overruns. Similarly, AI-enhanced BIM tools facilitate decision-making by analysing large datasets in real-time, providing valuable insights for project managers.

As the building sector undergoes a revolution, the demand for BIM qualified professionals is surging [10], several researchers highlighted the 'need for BIM skills' [11] in the construction sector. This demand encompasses advanced competencies like 4D scheduling (time-based project management) and 5D cost estimation, essential for effective project planning and resource allocation. However, these specialised skills are frequently underrepresented in CPM education curricula, resulting in a significant gap between industry expectations and graduate preparedness. To bridge this gap, educational institutions need to equip future professionals with these practical BIM skills, aligning their capabilities with current industry demands.

Construction 4.0 brings forth challenges to ensure students are up to date with the current needs of the industry, educators face the issues of staying updated with emerging trends and imparting the knowledge through improved curriculum and teaching strategies. A significant barrier in Australian institutions is the lack of BIM-trained faculty, which affects the consistency and quality of BIM education. Without adequate training, faculty members struggle to deliver comprehensive BIM instruction, resulting in varying levels of BIM competency among graduates. Addressing this faculty training gap is essential for ensuring that students receive a uniform and high-quality BIM education across institutions. Against this backdrop, the adoption of BIM in the construction industry of Australia has been slow and below full potential [12]. While countries like the US and Europe are advancing with robust BIM frameworks, Australia's slower adoption affects the competitiveness of its AECO sector. This lag highlights the need for a cohesive national framework to standardise BIM education and training across Australian institutions, better aligning with international standards and industry demands. The AECO sector in Australia recognised the need for BIM-trained professionals to meet the evolving technological and

project management demands [13]. Despite this growing need, the integration of BIM into higher education, specifically within CPM programs [14], remains inconsistent and fragmented across Australian universities.

1.2. BIM as a Solution

BIM provides a comprehensive digital representation of a building's physical and functional characteristics, facilitating better decision-making throughout the project lifecycle; it is a database that stores all the information on the components of a building [15] that can improve project efficiency by finishing projects on time and on budget [16,17]. BIM technology has been seen, tested, and proven as an innovative technology that can function perfectly well in the construction industry [17–19]. For example, BIM has been shown to reduce project costs by minimising errors and rework, improve timelines by streamlining project coordination, and enhance design accuracy by enabling visualisation and clash detection early in the design phase. It is a well-established technology through which construction project managers can achieve significant improvements in efficiency, cost management, and project delivery timelines by adopting to the improved processes and the associated software applications. The integration of internet of things (IoT) devices with BIM has revolutionised the concept of Digital Twins, enabling real-time data collection and analysis for enhanced decision-making. IoT sensors embedded in buildings provide continuous feedback on performance metrics such as energy consumption, occupancy patterns, and structural health. These insights enable dynamic updates to BIM models, creating an iterative cycle of design, monitoring, and optimisation.

BIM's potential to revolutionise the construction industry underscores the importance of embedding BIM education within CPM curricula. In Australia, however, adoption is hindered by gaps in BIM-specific education within the CPM field, contributing to a shortage of professionals skilled in critical areas such as 4D scheduling and 5D cost estimation. Embedding these skills into CPM curricula could significantly improve graduate readiness and industry alignment. One such challenge is the lack of skills and understanding of BIM within the Australian workforce [20]. Given that BIM is increasingly becoming a common practice for the construction industry, training and education of BIM should be pursued through a systematic approach [21]. A systematic approach ensures consistency across institutions, allowing graduates to meet a standardised level of BIM competency and thereby better support industry needs for digitally savvy professionals.

By equipping students with BIM skills, educational institutions can ensure that graduates are prepared to leverage this technology, thereby enhancing their employability and the industry's overall performance. Future employees in the construction industry are expected to bring higher levels of knowledge and skills relating to information technology [22] and perhaps even assist with the industry's digital transformation [23]. In response to this trend, the industry and academia realised that BIM education in university curricula is an important requirement for satisfying educational demands of the industry, and a notable body of research has reported strategies for AECO programs implemented to incorporate BIM in their curricula [24]. Pedagogical approaches in construction education play a significant role in shaping the adoption and implementation of emerging technologies. In this regard, Ref. [25] conducted a literature and bibliometric analysis to identify 25 barriers to the adoption of emerging technologies in construction. There is more pressure for a technically savvy workforce who are critical thinkers, innovators, and adaptable to current and future practices. Ref. [16] found an increasing integration of BIM into construction education through experiential process-based, problem-based, and project-based learning approaches.

1.3. Focus of the Review

This review paper focused on identifying the methods of BIM integration within global CPM education programs adopting BIM, the existing gaps and challenges in and understanding the industry's needs for BIM knowledge and competencies. These questions target critical issues in BIM education, such as the lack of standardisation, skills needed for industry integration, and methods to overcome common implementation barriers in educational settings. This study aimed to assess current BIM integration efforts through a systematic literature review and highlight areas requiring improvement.

This review covered many aspects of BIM integration in CPM education, such as curriculum development and implementation. The findings will be especially relevant in Australia, where BIM adoption lags due to inconsistent educational approaches and limited hands-on experience within CPM programs. It explored the specific methodologies used, the challenges, and the measurements of the success of using BIM technology in the project management education environment.

1.4. Review Objective(s)

This review aimed to address the fragmented adoption of Building Information Modelling (BIM) in Construction Project Management (CPM) education with the following steps:

- Identifying gaps in BIM education within CPM programs;
- Analysing existing methods of BIM integration into curricula;
- Proposing a structured framework for BIM adoption tailored to Australian universities;
- Offering actionable recommendations for aligning BIM education with industry needs.

To sum up, this paper focused on BIM for all levels of construction management education and holistically answered various research questions (RQ1–RQ6), including the following:

1. What are the global research trends of BIM integration and systematic approaches in education, and how do these compare to the Australian context?
2. At which education levels in the higher education (HE) system is BIM technology recommended for CPM education, in Australian Universities?
3. What are the competencies, knowledge requirements and software tool proficiency of using BIM technology required in construction project management, and how can we ensure this in teaching and learning?
4. What are the challenges of implementing the technology and strategies in developing a curriculum embedded with BIM technology?
5. What pedagogical strategies, approaches or methods are being pilot-tested in the academic environment, and what are their success rates?
6. How can the efficacy of using BIM technology for teaching and learning be measured?

The insights derived from these questions will inform strategies for developing curricula that address both fundamental and advanced BIM competencies, ensuring a balanced focus on technical skills, interdisciplinary collaboration, and practical industry applications. The answers to these questions and the findings will inform the development of a cohesive educational framework that aligns with industry requirements, ensuring that future construction project managers are proficient in BIM practices.

This review aimed to provide actionable recommendations for curriculum development and implementation strategies to bridge the identified gaps and better prepare graduates for the demands of the construction industry. For this, Section 2 detailed the methodology used to perform this systematic literature review, outlining the criteria for selecting and analysing relevant studies. Section 3 presented a summary and discussion of the main findings, while Section 4 addressed limitations and future research directions. Finally,

Section 5 provided a conclusion, synthesising the review's insights and their implications for BIM curriculum development in Australia and globally.

1.5. Findings of the Previous Reviews

Ten significant peer-reviewed literature reviews examined BIM in education, focusing on various aspects within higher educational environments. These studies collectively provided a comprehensive understanding of BIM's integration into academic curricula, the challenges encountered, and the strategies implemented globally. Table 1 summarises the previous review details.

Table 1. Previous systematic literature reviews.

No	Year	Author(s)	Aim of the Review
1	2013	[26]	Report major topics of interest for construction researchers and practitioners in US from 2000–2011 through analysis of IJCER technical papers
2	2016	[24]	Identify, synthesise, and report on research on BIM curriculum design in (AEC) education, and implement pedagogical strategies
3	2018	[27]	Assist AEC educators in curricula and course development for BIM education, and systematically review research methods, learning theories, methods, and approaches
4	2018	[28]	Provide an overview of global BIM education, and address the challenges in adopting to innovative BIM teaching strategies to introduce BIM in engineering curriculum in the past
5	2019	[29]	Comprehensively review the desirable skill sets of future construction management students the gaps from carefully chosen articles from construction management journals
6	2019	[30]	Understand the current state of BIM-enabled education by examining strategies, methods, and outcomes
7	2020	[31]	Review the existing approaches to Building Information Modelling for Construction Education (BfCE) in universities
8	2021	[32]	Understand if there are standardised guidelines or common approaches in BIM implementation within higher education AEC curricula worldwide
9	2023	[33]	Assess BIM's capabilities across project management knowledge areas within the construction industry
10	2024	[34]	Examine digital technology pedagogies in construction education

The earliest of these reviews, conducted by [26] systematically explored research trends in construction practice and education by analysing 167 papers from the International Journal of Construction Education and Research (IJCER) spanning 2000 to 2011. Utilising content analysis, they identified prevailing themes and developments in BIM education. Building upon this foundation, Abdirad and Dossick [24] presented a systematic review of 59 research papers published before March 2015, focusing on BIM curriculum design in AECO education. Their study highlighted gaps in research methods and curriculum designs, providing a critical synthesis of curriculum strategies along with their advantages and disadvantages.

Expanding the scope, Puolitaival et al. [27] used an inductive analysis method to review different research methods, data collection techniques, and disciplinary information related to BIM education. Analysing 170 articles from 2000 to 2017, they categorised the literature into learning theories, approaches, and methods, offering insights into educational practices. Similarly, Mutis et al. [28] compiled and analysed 304 articles retrieved between 2009 and 2015 that described BIM courses and teaching experiences. Through content

analysis, they outlined institutional obstacles in teaching BIM and documented progress in academic strategies and methodologies.

Focusing on skill acquisition, Agyemang et al. [29] conducted a three-phase review to thematically categorise the competencies required by construction management students. From 41 papers published between 1990 and 2018, they identified 86 essential skills. In parallel, Witt et al. [30] aimed to understand the state of BIM-enabled education by systematically reviewing 330 articles published from 2007 to 2018. They categorised the findings into BIM as a learning tool and BIM as a learning environment, shedding light on educational applications of BIM.

Addressing pedagogical approaches, Olowa et al. [31], performed a systematic literature review of BIM for Construction Education (BfCE) in universities, identifying 305 relevant articles including 44 specific cases. Using qualitative analysis and adopting a Straussian Theory Model (STM), they examined various teaching approaches and the conditions influencing BIM education. Besne et al. [32] applied the PRISMA methodology in their review of 23 articles, revealing a consensus on the necessity for common academic guidelines across universities to strategise curriculum modifications and teaching methods.

Recent studies delved into specialised areas of BIM education. Raza et al. [33] focused on identifying factors essential for measuring the application extent of Project Management Knowledge Areas (PMKAs) enhanced by BIM. Analysing 82 articles from 2000 to 2022, they identified 33 measurement factors and 66 BIM features that augment project managers' capabilities.

Besiktepe et al. [34] provided a systematic analysis of methodological pluralism and digital technology pedagogies in construction education. Reviewing over 100 papers from 1998 to 2024, they found that most studies employed quasi-experimental designs and integrated technological advancements like BIM and extended reality (XR) to teach core construction concepts.

Collectively, these literature reviews underscored the evolving landscape of BIM education in higher education institutions. They highlighted the critical need for standardised curricula, effective pedagogical strategies, and the integration of emerging technologies to equip future professionals with necessary competencies. The studies also pointed out ongoing challenges, such as institutional obstacles and the need for measurable outcomes, emphasising the importance of continued research and collaboration between academia and industry to enhance BIM education.

2. Methodology

2.1. Systematic Literature Review

Systematic review methodology can be distinguished from narrative reviews of the literature through its emphasis on transparent, structured, and comprehensive approaches to searching the literature and its requirement for formal synthesis of research findings. The overarching epistemology adopts both interpretivist and pragmatist philosophical stances, couched within grounded theory, to critically analyse extant literature on construction management curriculum development. The purpose of this study was to systematically review the literature to provide a comprehensive understanding of research methodologies utilised in teaching BIM technologies in construction education. The systematic review methodology is associated with evidence-based practice and has been widely applied particularly in the field of healthcare delivery. Since the late-1990s, it has also become the "literature review methodology of choice" for some in the educational research community [35].

Adopting to BIM technology or integrating BIM technology into the curriculum boils down to use of digital technology and learning and applying a set of software applications for use in adopting to BIM technology in design and Construction. This study used

Systematic Literature Reviews (SLR) adopting the Kitchenham approach [36,37] with guidelines for performing systematic literature reviews that are appropriate to the needs of software engineering researchers. The methodology of this study comprised two main phases: (i) Review with PRISMA and (ii) Qualitative analysis. The first phase focuses on the review process following the 'Preferred Reporting Items for Systematic Reviews and Meta-Analyses' (PRISMA) steps [38]. The steps of this research involving, conducting the review, reporting the review are shown in Figure 1 below.

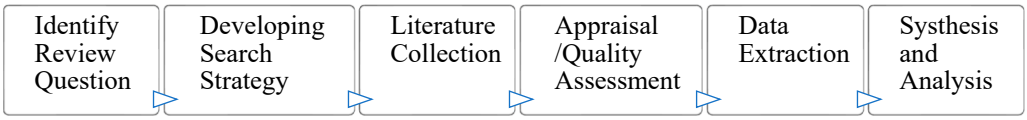


Figure 1. Steps of this Review.

The recommended Joanna Briggs Institute (JBI) approach based on PRISMA guidelines is adopted to the study selection, appraisal, data extraction, synthesis, and critical appraisal [39].

2.2. Review Question(s)

The research objective is to examine the status quo of BIM integrated teaching and learning strategies in Construction Project Management (CPM) Education around the world and reported the experiences, outcomes, and findings since last decade and to date. Ref. [40] suggest using the PICOC (Population, Intervention, Comparison, Outcome, Context) criteria to frame research questions. The questions for the review are as follows:

- What is the global status of BIM integrated teaching and learning in Construction Project Management (CPM) Education and the observed gaps?
- What are the issues (drivers, challenges, etc.) that affect BIM integration in CPM Education?
- What are the required knowledge and BIM competencies which the construction industry seeks from the graduates of Construction Project Management Studies?

2.3. Database Selection

Major literature databases, viz., ASCE Library, EBSCOhost Web, Scopus, and Web of Science Core Collection were selected to ensure good coverage of the literature available, i.e., peer-reviewed journal articles and conference papers.

2.4. Search Strategies

The following Boolean phrase of keyword combinations was used in advanced searches to match "Anywhere in document" (i.e., all text and all fields):

("BIM") OR "building information modelling") OR ("building Information modeling") AND ("construction project management education") OR ("construction education") OR ("engineering education") OR ("construction management education") OR ("construction management teaching") AND ("tertiary education') OR ("curriculum") OR ("competencies") AND ("construction industry") AND PUB YEAR > 2010 AND PUB YEAR < 2024. The "TITLE-ABS-KEY" indicates a journal or conference article title, abstract, and keywords. For this study, the time frame considered was between 2010 and 2024. The literature search was conducted in July/August 2024, with an initial search producing 233 articles with the keywords mentioned earlier. Table 2 lists the inclusion and exclusion criteria adopted for the initial search of the databases.

Table 2. Inclusion/exclusion criteria.

Inclusion	Exclusion
1. Studies focused on BIM integration in construction project management courses or curricula, particularly those within an educational or training context. 2. Research conducted within tertiary education institutions, including universities and vocational training colleges, with a specific emphasis on BIM Integration into the teaching curriculum. 3. Empirical studies, framework proposals, and case studies that offer insights into effective BIM teaching strategies, curriculum development, and educational outcomes. 4. Literature published in English from 2014 onwards, to ensure the review captures the most recent developments and trends in BIM education. 5. Peer-reviewed articles, conference papers, and official reports from recognised industry and academic sources.	1. Studies involving BIM integrated education, but not directly related to construction project management. 2. Studies that focus solely on technical aspects of BIM without educational implications, studies on AR/VR technologies, though it is supported by BIM technology. 3. Research outside the scope of tertiary education, such as professional development programs not associated with academic institutions. 4. Non-English literature, unless significant to the aim of research and a reliable translation is available. 5. Opinion pieces, editorials, and non-peer-reviewed literature that do not provide empirical evidence or detailed analysis relevant to BIM education.

Figure 2 shows the PRISMA Flow Diagram of the search and selection of articles, a detailed review process in stages as recommended processes of the JBI Sumari method and protocol. Table 3 provides the types of articles and the detailed distribution of articles year-wise, totalling 99 in all.

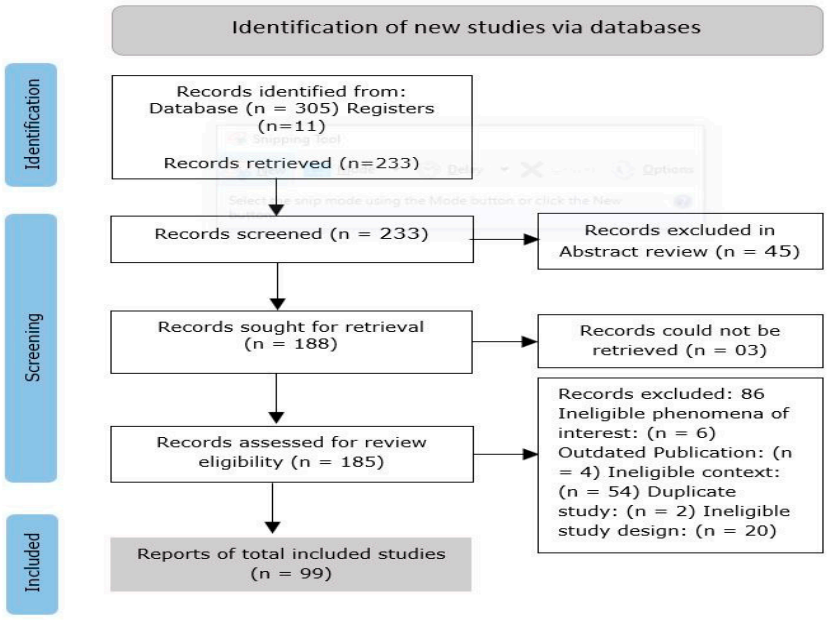


Figure 2. PRISMA flow diagram of search and study selection.

Table 3. Summary of distribution of themes across the reviewed articles.

Theme	Articles	Percentage
Curriculum Development	54	55%
Pedagogical Approaches	20	20%
Competencies	25	25%

2.5. Inclusion/Exclusion Criteria

The specifics of the inclusion and exclusion criteria are as follows:

Inclusion Criteria

- Studies focused on BIM integration in CPM education or curricula;
- Empirical studies, framework proposals, and case studies published in English form the year 2010 to 2024;
- Peer-reviewed journal articles and conference papers.

Exclusion Criteria

- Studies focused on technical aspects of BIM without educational implications;
- Non-English publications unless significant and reliably translated;
- Opinion pieces and editorials lacking empirical evidence.

The exclusion of emerging technologies such as VR, AR, and generative design in Table 2 was intentional to focus on core BIM competencies directly linked to CPM curricula. These technologies, while relevant, represent supplementary tools that extend beyond foundational BIM training. Future research could explore their integration into advanced stages of CPM education. And Table 2 shows the detailed inclusion and exclusion criteria for searching the database for articles.

2.6. Data Extraction and Analysis

The dissemination of research on construction education, particularly focusing on recent technological advancements in higher education, was primarily done through journals and conference proceedings. The articles were further screened through the recommended process of (i) reading the abstract, (ii) full-text reading, and (iii) appraisal, and the articles were short-listed to 99. Of the 99 papers reviewed, 70 were published in academic journals, 26 in conference proceedings, and 2 reports and a book chapter. The interdisciplinary nature of construction education research is evident through its widespread distribution in various journals and conference proceedings. Table 4 summarises the articles type-wise, and Table 5 provides the breakup of articles year-wise from 2010 to 2024.

Table 4. Number of publications organised by type.

Type	Count
Journals	70
Conference Paper	26
Report	02
Book	01
Total	99

Table 5. Number of publications per year since 2010.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Count	2	1	0	10	7	7	10	5	13	7	9	9	10	7	2

The variety of publication venues suggests a comprehensive approach to addressing different aspects of construction education, from technological integration to pedagogical methods and practical applications. The 99 papers were grouped using the keywords stated in the search strategy. The shortlisted articles include 54 studies (55%) on curriculum

development, 20 studies (20%) on pedagogy, and 25 studies (25%) on skills and competencies, refer to Table 3. The distribution of the publications is more concentrated in the US, followed by the UK, Europe, Australia, and New Zealand. The reason could be that BIM integration into construction project management education has emerged in developed countries and spread worldwide. Table 6 provides the breakup of articles globally.

Table 6. Number of publications—global distribution.

Type	Count
Asia	12
Africa	03
Europe	13
UK	11
S America	03
US	41
Australia/NZ	16
Total	99

2.7. Documentation and Meta-Analysis

The following are details of the step-by-step procedure of how the literature review was documented and the selected publications were analysed using 'JBI Sumari' software.

1. Prepare a review protocol, with title, review question, inclusion/exclusion criteria, etc.
2. Import the studies collected as references through the EndNote library into the JBI Sumari portal.
3. Conduct initial 'Abstract' level screening and shortlist the studies for further detailed appraisal.
4. All studies included in the review are subject to a critical appraisal process with a methodology named 'ConQuel' using the JBI-Qualitative Assessment and Review Instrument (JBI-QARI) [41]. Conduct an appraisal of the references using the JBI-checklist with a set of questions covering the criteria to be met through 'Full-text' reading of all the shortlisted studies in the initial screening for dependability and quality check with a ranking system. References with higher rank are included for the next data extraction process.
5. Carry out data extraction for the references considered using JBI Sumari 'data sheet' and execute data synthesis, place the findings, and review outcome.

Standardised data extraction tools promote similar data extraction across all included studies and are required for JBI systematic reviews. The data extracted will include specific details about the populations, context, culture, geographical location, study methods, and the phenomena of interest relevant to the review question and specific objectives. The findings and their illustrations will be extracted and assigned a level of credibility. Qualitative research findings will, where possible, be pooled using JBI SUMARI with the meta-aggregation approach. This will involve the aggregation or synthesis of findings to generate a set of statements that represent that aggregation through assembling the findings and categorising these findings based on similarity in meaning. These categories are then synthesised to produce a single comprehensive set of synthesised findings that can be used as a basis for evidence-based practice [39]. Tables 7 and 8 provide an overview of the distribution of research articles globally and within Australia and New Zealand, categorized by research focus, type, and references. This contextual positioning helps readers

understand the broader and regional landscape of BIM integration in CPM education while maintaining the logical flow of the meta-analysis discussion.

Table 7. BIM integration into CPM education: research articles and global efforts.

Research Focus	No of References		Reference Type	References
Curriculum Development	49	34	Journal Articles	[15,22,24,28,32–34,42–65]
		14	Conference Paper	[18,26,31,66–75]
		1	Book	[28]
Pedagogy	19	13	Journal Articles	[27,31,76–85]
		6	Conference Paper	[30,86–90]
Competencies	17	13	Journal Articles	[91–103]
		4	Conference Paper	[19,29,104,105]

Table 8. BIM integration into CPM education: research articles from Australia and New Zealand.

Research Focus	No of References		Reference Type	References
Curriculum Development	5	3	Journal Articles	[14,106,107]
		1	Conference Paper	[108]
		1	Report	[109]
Pedagogy	1	1	Conference Paper	[110]
Competencies	8	6	Journal Articles	[13,111–115]
		1	Conference Paper	[116]
		1	Report	[117]

3. Results and Discussion

3.1. Addressing Research Questions

This section provided a detailed discussion addressing the research questions outlined in Section 2.3. The focus was on the theoretical foundation and objectives of this research, derived holistically from the data extracted in this systematic literature review.

RQ1: What are the research trends of BIM integration and systematic approaches in CPM education, and how do these compare to the Australian context?

The reviewed articles were categorised by geographic origin to analyse the regional focus of BIM adoption in education. Over the past 24 years, and more significantly in the last decade, there has been a substantial increase in research on construction education (refer to Figure 3 and Table 5). This surge is predominantly observed in developed countries, with the United States, the United Kingdom, and Australia being the most active regions (refer to Figure 4a,b and Table 6). Approximately 42% of studies originated in the United States, reflecting its early adoption of BIM in education. The dominance of US-based cases may be attributed to the early adoption of BIM in the US construction industry and the proactive role of professional organisations and federal agencies in promoting BIM education [31]. These countries have contributed the most publications and have the strongest academic networks in construction education research.

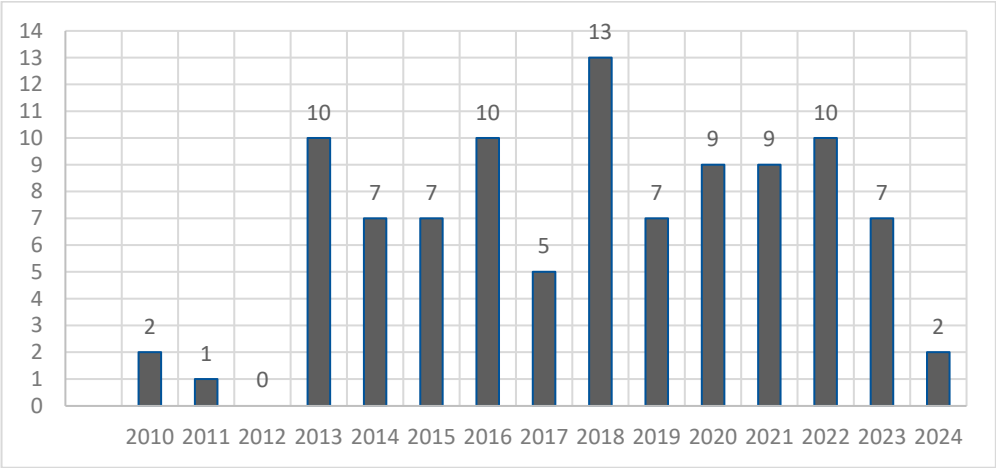
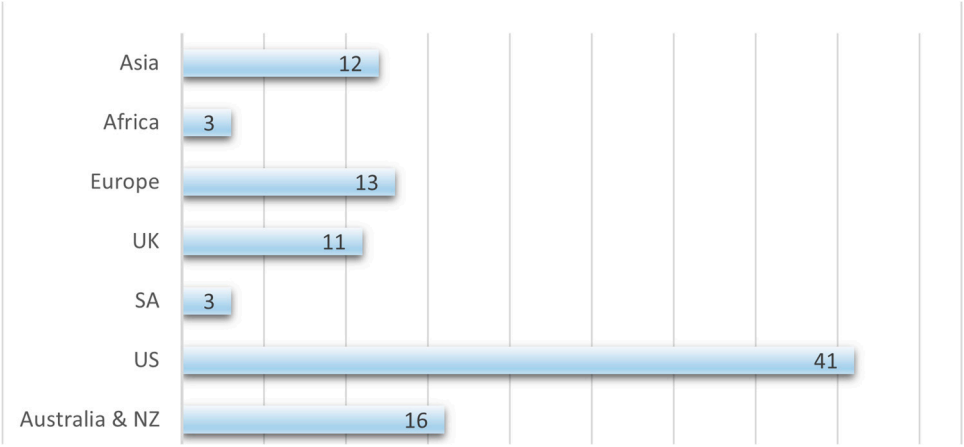
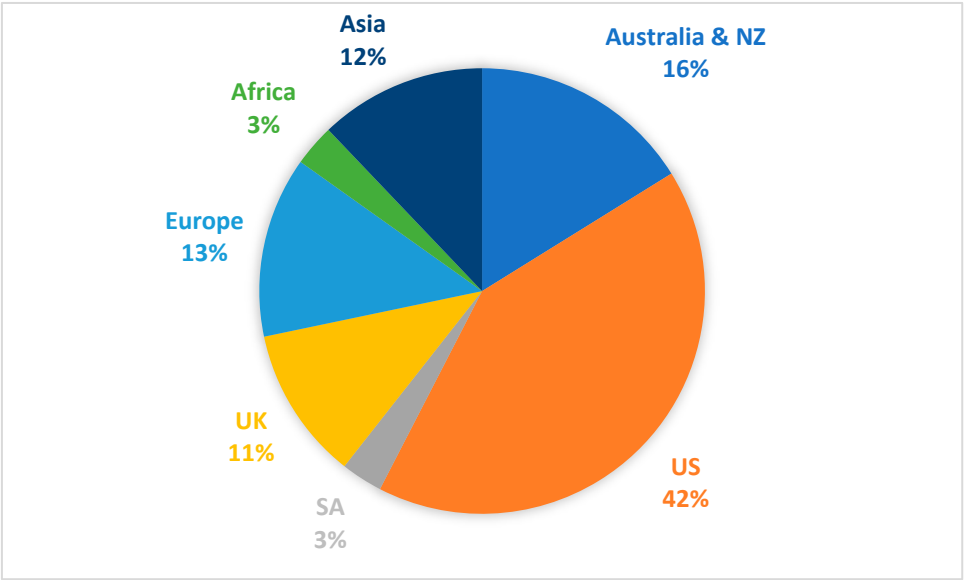


Figure 3. Publications per year since 2010.



(**a**)



(**b**)

Figure 4. (**a**) Global distribution of publications; (**b**) global distribution of publications.

The literature was analysed for thematic patterns using cross-tabulation. Table 3 summarises the distribution of themes across the reviewed articles. More than half of the 99 reviewed articles (54 papers) focused on developing revised or restructured CPM

education curricula that integrate BIM knowledge. Of these, 37 were peer-reviewed journals and 15 were academic and industry conference papers. Evidently, there is more research on CPM education than on general BIM integration in AECO education, especially in the US, the UK, and Europe. Following curriculum development, the assessment of BIM competencies and skills was the next most researched area with 25 studies, while improved and innovative pedagogical approaches accounted for around 20 studies. It is observed that the curriculum development dominated the research focus, reflecting its critical role in BIM education. However, pedagogical approaches were under-represented, indicating a need for further research.

Many challenges are outlined and methodical approaches as remedial measures are recommended in the research findings. Developing a BIM curriculum for CPM education, adopting a particular teaching and learning method (pedagogy), creating a unified curriculum across all the institutions, meeting the industry requirement in terms of BIM skills and competencies, and equipping the faculty members with knowledge of BIM, software competencies and technology-based teaching, are among the notable challenges mentioned in the studies reviewed. Table 9 provides a condensed list of recommended remedial measures extracted from the studies that are proposed to be included in the BIM curriculum.

Table 9. Condensed list of recommended remedial measures extracted from the studies.

No	Recommended Remedial	Articles	References
1	Academia–Industry Collaboration	15	[19,21,24,32,33,43,46,48,49,53,60,82,86,91,95]
2	BIM Competencies	20	[14,18,21,30,43,53,56,60,62,70,80,82,91,96–98,105,111,112,114]
3	Construction Process upgrade	3	[60,74,104]
4	Experimental Learning	21	[14,22,25,47,50,52,55–57,77,79–82,85,86,95,103,111]
5	Faculty Expertise	6	[30,32,46,49,53,71]
6	Interdisciplinary Collaborative Learning	16	[14,21,24,30,46,49,52,57,60,77,79,87,94,96,112]
7	Modular Curriculum	7	[24,49,53,55,85,112,114]
8	Unified Curriculum	6	[18,21,32,43,49,77]

RQ2: At which education levels in the higher education (HE) system is BIM technology recommended for CPM education in Australian universities?

A program-wide approach to BIM integration, rather than individual course applications, provides students with a holistic understanding of project management, allowing them to connect disparate concepts into a comprehensive skill set. The authors of [14] presented the following three-tier implementation strategy for BIM:

- **Instructive (Basic Competency):** Introducing fundamental BIM concepts and skills;
- **Illustrative (Graphic Reference):** Using BIM as a visual tool to support learning;
- **Immersive (Problem-Based Learning):** Engaging students in experiential learning through real-world BIM applications.

This typology helps structure BIM adoption progressively across various courses, enabling students to develop skills over time.

Similarly, the author of [118] suggested the following comprehensive three-level framework for integrating BIM into Construction Management (CM) education:

- **Level 1: Fundamentals**—Introduce basic BIM concepts, terminology, and tools to beginners;
- **Level 2: Application**—Teach students to apply BIM in project management tasks like scheduling (4D) and cost estimation (5D), emphasising practical, hands-on learning and collaboration;

- **Level 3: Advanced**—Integrate complex applications such as clash detection, facility management, and interdisciplinary collaboration, preparing students for professional industry roles.

Recent qualitative research in the US by Dang et al. [42] covering 13 universities across 11 states found varied approaches to BIM integration:

- Introducing BIM in lower-level courses;
- Creating dedicated upper-level or graduate BIM courses;
- Transforming existing courses to include BIM topics;
- Integrating BIM into capstone design projects or student competitions.

These courses cover BIM concepts, software applications, design coordination, clash detection, construction scheduling (4D), cost estimation (5D), and sustainability (6D and 7D), with a primary focus on 3D, 4D, and 5D dimensions.

Lee et al. [54] found that most BIM education in CPM programs focuses on introductory-level BIM, mainly teaching software skills without integrating BIM into broader construction management processes. Only 32% of programs offer upper-level courses. There is a need for CPM programs to extend BIM education to include advanced courses that address industry-specific needs, covering topics like project coordination, scheduling, constructability, clash detection, phase planning, and site utilisation. The recommendation is to offer introductory BIM courses at the freshman or sophomore level, followed by advanced courses in junior and senior years, allowing students to build on their skills and apply them to real-world construction problems.

Proposed BIM Educational Framework:

To enhance BIM integration in Construction Project Management (CPM) education, this study proposed a three-phase educational framework tailored to the Australian context.

Phase 1: Foundational Training

Objective—Build students' foundational understanding of BIM concepts and software tools.
Scope—Introduce BIM basics, such as digital modelling, 3D visualisation, and data management.
Teaching Approaches—Lectures, tutorials, and introductory software exercises.
Technologies—Basic BIM platforms (e.g., Autodesk Revit, Navisworks).

Phase 2: Advanced Techniques

Objective—Develop students' ability to apply BIM in practical, project-based scenarios.
Scope—Focus on 4D (scheduling), 5D (cost estimation), and interdisciplinary collaboration.
Teaching Approaches—Problem-based learning (PBL), simulations, and case studies.
Technologies—Advanced tools such as clash detection, generative design, and VR/AR integration.

Phase 3: Industry Collaboration

Objective—Bridge the gap between academic training and professional practice.
Scope—Engage students in real-world projects and internships with industry partners.
Teaching Approaches—Capstone projects, internships, and industry-sponsored workshops.
Technologies—Integrated BIM workflows involving cloud-based collaboration tools (e.g., BIM 360).

This phased framework aligns with global trends in BIM education while addressing the specific challenges faced by Australian universities. It emphasises incremental learning, hands-on application, and interdisciplinary collaboration, ensuring graduates are equipped to meet industry demands.

RQ3: What are the competencies, knowledge requirements, and software tool proficiency of using BIM technology required in construction project management, and how can we ensure this in teaching and learning?

The establishment of a BIM Body of Knowledge (BIM BOK) outlines the core competencies required in BIM, providing a standardised set of knowledge, skills, and abilities (KSAs) essential for BIM professionals. This ensures consistency and coherence in BIM education and practice. Foundational BIM competencies span several core knowledge areas:

- **Technical Knowledge:** Skills in digital modelling, data management, and using BIM tools;
- **Process Knowledge:** Competencies in project workflows, lifecycle management, and data exchange;
- **Collaboration Skills:** Emphasis on communication and coordination across disciplines, critical for managing BIM projects in the AECO industry.

The BIM BOK framework classifies competencies based on various roles, such as BIM technicians, coordinators, and managers, recognising that each role demands different expertise. This classification helps define clear career paths within BIM professions and guides training programs to tailor content to role-specific needs [21,24,52,53,97].

Mandicak et al. [96] suggest that current BIM training programs are insufficient in developing the full spectrum of digital and managerial competencies required in project management. A more structured and comprehensive approach to BIM training, particularly focused on industry-relevant applications, is recommended to bridge this skills gap. Incorporating collaborative learning modules into BIM training can improve teamwork, communication, and project data exchange skills, reflecting the industry's growing emphasis on cross-functional collaboration facilitated by BIM.

RQ4: What are the challenges of implementing the technology and strategies in developing a curriculum embedded with BIM technology?

Developing a BIM curriculum presents several challenges, including the following:

- **Resource Limitations:** Need for up-to-date software, hardware, and technical support;
- **Faculty Expertise:** Lack of qualified instructors proficient in BIM tools and methodologies;
- **Curriculum Constraints:** Balancing technical training with soft skills within limited course time.

Industry collaboration can help alleviate some challenges by providing resources and training support, but the process remains complex [53]. A significant barrier to BIM adoption in HEIs is the lack of faculty training and engagement. Most faculty members in these institutions lack BIM knowledge, limiting their ability to incorporate BIM into teaching effectively. Faculty training programs are often not institutionalised, and BIM knowledge among faculty members remains limited, contributing to a lower maturity level in the policy field. The lack of a formal BIM policy and strategic direction is prevalent across HEIs. There is minimal institutionalisation of BIM, and many programs rely on individual faculty initiatives rather than coordinated, institution-wide strategies for BIM adoption. HEIs often lack awareness of federal policies promoting BIM adoption, further highlighting the need for a formal policy to support and expand BIM education [46].

This study identified challenges in implementing a BIM-integrated curriculum, particularly the need for sufficient resources, technology, and instructor expertise to support BIM learning. These requirements ensure students have consistent access to software, suitable hardware, and knowledgeable guidance throughout their coursework [60,119].

This review identified several challenges associated with BIM in academic settings, including the following:

- **Technical barriers:** Limited resources in institutions for advanced software, hardware, and technical support;
- **Faculty training:** Many instructors lack expertise in BIM, making it challenging to teach BIM-integrated courses effectively;

- **Curriculum constraints:** Institutions struggle to fit BIM training within existing curricula due to time limitations and a need to cover various foundational topics in AEC disciplines.

Additionally, rapid developments in BIM technology create uncertainty about what specific skills and software versions to include in curricula [30]. Another study identified significant gaps in collaboration between higher education institutions (HEIs) regarding construction management education. Many programs develop in isolation, often reflecting the personal preferences of program leaders rather than a collective body of knowledge or best practices [43].

One of the primary challenges identified in the research is the lack of faculty expertise in BIM. Many educators are not adequately trained to teach advanced BIM applications, which limits the depth and quality of BIM education. This challenge is particularly significant in institutions where faculty have limited practical experience with BIM tools and workflows. The research emphasised the need for continuous professional development for faculty and students. Given the rapid evolution of BIM technology, educators must stay updated with the latest tools and techniques to ensure they are teaching relevant and up-to-date content. Continuous learning opportunities, such as workshops and certifications, are critical for improving BIM education [49]. Key challenges in BIM education include resource constraints (such as access to BIM software and experienced faculty), time limitations within packed AEC programs, and varying levels of BIM integration across institutions. These factors create inconsistencies in BIM competency among graduates. This study calls for further research into pedagogical methods that balance theory with hands-on BIM experience and studies on long-term learning outcomes and the impact of BIM education on career development. Exploring graduate-level BIM training and assessment methods is also suggested [24].

RQ5: What pedagogical strategies, approaches or methods are being pilot-tested in the academic environment, and what are their success rates?

A modular approach to BIM education enables flexibility, allowing students to progress from foundational skills to more advanced competencies. This structure supports diverse learning paths and accommodates students' varying experience levels, ensuring a comprehensive understanding of BIM from basics to complex applications [53,55]. Several strategies are found effective for BIM curriculum development, including:

- **Modular Curriculum Design:** Allows flexibility and accommodates students' varying experience levels, progressing from foundational skills to advanced competencies;
- **Project-Based Learning:** Engaging students in real-world projects enhances their practical BIM skills;
- **Collaborative Learning:** Emphasising teamwork and multidisciplinary collaboration mirrors industry workflows and is essential for effective BIM education;
- **Incremental Learning Approach:** Introducing BIM concepts progressively, from foundational modelling skills to advanced data management and project coordination, supports a comprehensive learning experience.

This study suggested that institutions adopt a flexible, modular curriculum design to accommodate introductory and advanced BIM topics. This approach allows students to build skills and adapt to industry needs while managing curriculum constraints [24,56]. This study categorised BIM education cases into two primary types: BIM-focused and BIM-enabled. BIM-focused, where the emphasis was on teaching students to use BIM tools for specific tasks. BIM-enabled, where BIM was used as a vehicle for learning broader construction concepts. This finding suggests that while universities increasingly incorporate BIM into their curricula, the focus remains on tool-based education rather than using BIM as

an integrated learning environment. An increasing adoption of problem-based and project-based learning approaches has also been observed, reflecting a shift toward experiential and hands-on BIM education [31].

The BIM Studio approach [82], developed for CPM education, provided an immersive and integrative learning experience. Using BIM in the studio model allowed students to synthesise better and apply knowledge from multiple CPM courses. This immersive learning environment helped bridge the gap between theoretical knowledge and practical application in construction project management. The BIM Studio fostered a collaborative learning environment, aligning the educational approach with the increasingly collaborative nature of the construction industry. Students worked together on BIM-related tasks, which encouraged teamwork and multidisciplinary collaboration, skills essential for future construction project managers; this approach can be scaled and integrated across multiple courses in CPM programs. This study recommended expanding the BIM Studio to create a program-wide curricular strategy, with BIM becoming a central tool for teaching CPM and related subjects.

The competency-based learning framework used in the BIM capstone course was found to be effective in enhancing students' practical skills and knowledge integration. The students demonstrated improved competencies in applying BIM tools to real-world construction management challenges, particularly in project planning, cost estimation, and scheduling. The BIM capstone course successfully served as a platform for integrating technical, managerial, and soft skills. Students applied theoretical knowledge and practical BIM tools to complete complex construction projects, demonstrating a strong connection between classroom learning and industry expectations [52].

The authors of [100] reported that blended learning (a combination of online and in-person instruction), site visits, case studies, and interactive experiences (such as project simulations and educational games) effectively engage students. These methods bridge theory and practice, allowing students to apply theoretical knowledge to practical scenarios, which is particularly beneficial for construction management education.

Emerging Technologies in BIM Education

Recent advancements in technology have significantly expanded the scope of BIM education. Emerging technologies, such as generative design, virtual reality (VR), augmented reality (AR), and coding, offer innovative methods to enhance teaching and learning:

- Generative Design—Enables students to explore multiple design options rapidly by using algorithms to optimise building performance. This approach fosters creativity and data-driven decision-making, aligning with industry expectations for efficiency and sustainability.
- Virtual Reality (VR)—Immersive VR environments allow students to interact with 3D models in real time, providing a hands-on understanding of construction sequences and spatial relationships.
- Augmented Reality (AR)—AR tools overlay digital information onto physical spaces, helping students visualise complex designs and collaborate in real-world settings.
- Coding and Automation—Teaching students programming skills (e.g., Python, Dynamo for Revit) prepares them to customise BIM tools, automate repetitive tasks, and enhance project workflows.

While these technologies offer immense potential, integrating them into the curriculum presents challenges, including high costs, technical complexities, and the need for instructor training.

Pedagogical Impacts of BIM Tools and Technologies

- The intersection of pedagogy and technology has transformed traditional teaching methods in BIM education. Key impacts include the following:
- Active Learning—BIM tools enable interactive sessions where students work on live projects, promoting critical thinking and problem-solving skills;
- Collaborative Learning—VR and AR facilitate group activities, allowing students from diverse disciplines to collaborate on shared virtual models, mimicking real-world project environments;
- Flipped Classrooms—By assigning foundational BIM concepts as pre-class material, instructors can focus on hands-on activities and advanced problem-solving during class time.

These approaches improve student engagement, deepen understanding, and prepare students for the collaborative nature of the construction industry. However, effective implementation requires instructors to adopt technology-driven pedagogical strategies and assess their impact on student outcomes.

To ensure that emerging technologies are effectively integrated into BIM education, curricula should be redesigned to include dedicated modules on these tools. For example, an introductory module on generative design in Year 2 could focus on algorithmic thinking, while Year 3 could incorporate immersive technologies such as VR and AR to simulate construction workflows. Additionally, capstone projects should encourage students to use coding and automation to solve real-world challenges, bridging the gap between academic learning and industry practice.

The integration of emerging technologies into BIM education is not without challenges. High costs associated with VR headsets, AR devices, and software licenses can deter institutions from adoption. Additionally, the steep learning curve for both students and instructors require ongoing training and support. To address these barriers, universities can collaborate with industry partners to secure funding and access cutting-edge tools. Such partnerships not only mitigate costs but also expose students to real-world applications, enhancing their employability.

RQ6: How can the efficacy of using BIM technology for teaching and learning be measured?

Boes et al. [46] introduce a BIM maturity model designed explicitly for higher education institutions (HEIs) and organised around three core fields: policy, process, and technology. Each field contains multiple criteria and is divided into five maturity levels: Pre-BIM, Initial, Defined, Integrated, and Optimised. This model allows HEIs to systematically assess their BIM integration level, providing insights into areas requiring further development. The BIM Maturity Model (m^2 BIM-HEI) developed in this study is a tool for ongoing assessment and improvement in HEIs. It provides a framework to track progress over time, helping institutions identify specific areas for intervention and align their curricula with industry demands.

This framework connects BIM competencies, learning objectives, and assessment tasks with industry roles and practices, ensuring students acquire the necessary skills to transition smoothly into the workforce.

3.2. Summary

Based on the results of this review, a comprehensive insight was achieved into the global efforts to integrate BIM technology in CPM education. The research trend covered in RQ1 shows a significant increase in research focused on BIM for Construction Education over the past decade. Their focus, in the order of primary importance, is on curriculum

development, competency enhancement and pedagogical approaches. In RQ2, it is evident that most of the researchers recommend a program-wide approach to BIM implementation with an incremental increase in the complexity of BIM tools and processes embedded into the curriculum systematically spread across all subject areas from the freshman or sophomore level, followed by more advanced, upper-level BIM courses in junior and senior years. A modular approach to BIM education enables flexibility, allowing students to progress from foundational skills to more advanced competencies. Interdisciplinary collaborative learning is another strategy that advocates for adequate knowledge of BIM usage in the industry. Responses to RQ3 list the required foundational BIM competencies across several core knowledge areas, such as Technical Knowledge—Skills in digital modelling, data management, and using BIM tools; Process Knowledge—Competencies in project workflows, lifecycle management, and data exchange; Collaboration Skills—Emphasis on communication and coordination across disciplines, critical for managing BIM projects in the AECO industry. The BIM BOK framework classifies competencies based on various roles, such as BIM technicians, coordinators, and managers, recognising that each role demands different expertise. Addressing RQ4, developing a BIM curriculum presents challenges, including the need of up-to-date resources, qualified instructors, and a balance between technical training and soft skills. Industry collaboration helps alleviate some of these challenges by providing resources and training support, but it remains a complex process. HEIs often lack awareness of federal policies promoting BIM adoption, highlighting the need for a formal policy to support and expand BIM education. The top three pedagogical approaches (RQ5) for BIM education are project-based/problem-based learning, collaborative learning, and incremental learning, among all other pilot-tested pedagogies. BIM-focused, where the emphasis was on teaching students to use BIM tools for specific tasks; BIM-enabled, where BIM was used as a vehicle for learning broader construction concepts, are the strategies for effective education methodologies. The efficacy of BIM technology-enabled education (RQ6) can be gauged through the 'BIM Maturity Model', a tool for ongoing assessment and improvement which provides a framework to track progress over time, helping institutions identify specific areas for intervention and align their curricula with industry demands. This framework connects BIM competencies, learning objectives, and assessment tasks with industry roles and practices, ensuring students acquire the necessary skills to transition smoothly into the workforce.

4. Limitations and Future Directions

The systematic literature review methodology involves transparent and time-intensive screening of articles at the abstract level and in the full-text review stage. It is recommended that a minimum of two persons carry out this exercise to avoid theoretical bias in the selection process. However, in this review, the primary author solely screened the studies individually, owing to the resource constraints. For this review, journal articles and conference papers published from 2000 to Q2 of 2024 in significant databases that were in English have been included. Non-English publications from European, North American, and Asian literature are excluded, but future research can include articles translated into English. The decision to include articles from the year 2000 aligns with the timeline of BIM's introduction and diffusion within the AECO sector. Early 2000s literature provides foundational insights into the initial adoption of BIM, highlighting challenges and opportunities that remain relevant today. This broader scope ensured a comprehensive understanding of BIM's trajectory in education and industry. The review was limited only to the extent of BIM technology usage as teaching and learning tools and excludes other technology supported by BIM, such as 3D printing, robotics, and virtual, mixed, and augmented reality (VR, MR, AR), which are used in the construction industry. These technologies were excluded

to maintain the study's focus on core BIM competencies directly linked to curriculum development. While these technologies enhance construction processes, their integration into BIM education requires separate analyses due to their specialised applications. Future research could explore their role in complementing BIM pedagogy.

Future research should focus on the potential usage of BIM for vocational education and trade certification offered through Technical and Further Education (TAFE) as part of tertiary education in Australia to upskill the industry workforce.

5. Conclusions

This review addressed the need to align CPM education with the evolving digital requirements of the construction industry, particularly through the integration of BIM. The research problem is rooted in the fragmented and inconsistent adoption of BIM across CPM curricula, which limits graduates' preparedness for industry roles that increasingly demand digital and collaborative skills. This study systematically reviewed the global academic literature on BIM education, identifying gaps in standardised curricula, practical training, and interdisciplinary collaboration, with a focus on the Australian context. Using a systematic literature review methodology, the paper synthesises findings from multiple studies to provide insights into effective pedagogical strategies and curriculum structures that foster BIM competency. Key contributions of this review include the identification of actionable curriculum enhancements and methods to bridge the academia–industry divide in BIM education. Collaboration between academic institutions and companies is critical for integrating BIM into professional training. Potential approaches include the following: (a) industry-sponsored BIM labs in which universities can partner with companies to provide students with access to state-of-the-art tools and real-world project data; (b) internship programs that offer structured internships to allow students to gain hands-on experience with BIM applications under industry supervision; and (c) joint curriculum development in which courses are co-developed with industry experts to ensure alignment with current practices and future trends.

The Australian government has increasingly recognised the importance of Building Information Modelling (BIM) in higher education to equip graduates with industry-relevant skills. Policies and initiatives focus on fostering collaboration between educational institutions and industry stakeholders, integrating BIM into architecture, engineering, and construction curricula. Government-supported programs, such as those from Standards Australia, promote the use of standardised BIM protocols and frameworks. These efforts aim to address workforce skill gaps, enhance productivity, and align with the national push for digital transformation in the construction sector.

Future directions emphasise the importance of establishing unified curriculum standards and advancing faculty training, ultimately aiming to cultivate a workforce that is adept in BIM and ready for the technological advancements in construction project management.

Author Contributions: Conceptualization, X.P. and N.I.; methodology, X.P. and N.I.; software, X.P.; validation, X.P., N.I. and Z.V.; formal analysis, X.P.; investigation, X.P.; resources, X.P., N.I., Z.V.; data curation, X.P.; writing—original draft preparation, X.P., N.I.; writing—review and editing, X.P., N.I., Z.V.; visualization, X.P.; supervision, N.I, Z.V.; project administration, N.I, Z.V. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: During the preparation of this article, the authors used AI tools to improve readability and language. After using these tools, the authors reviewed and edited the content as needed. They take full responsibility for the content of the publication.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. De Souza, A.S.C.; Debs, L. Concepts, innovative technologies, learning approaches and trend topics in education 4.0: A scoping literature review. *Soc. Sci. Humanit. Open* **2024**, *9*, 100902. [CrossRef]
2. El Jazzar, M.; Schranz, C.; Urban, H.; Nassereddine, H. Integrating construction 4.0 technologies: A four-layer implementation plan. *Front. Built Environ.* **2021**, *7*, 671408. [CrossRef]
3. Forcael, E.; Ferrari, I.; Opazo-Vega, A.; Pulido Arcas, J. Construction 4.0: A Literature Review. *Sustainability* **2020**, *12*, 9755. [CrossRef]
4. Rao, T.V.N.; Gaddam, A.; Kurni, M.; Saritha, K. Reliance on artificial intelligence, machine learning and deep learning in the era of industry 4.0. In *Smart Healthcare System Design: Security and Privacy Aspects*; Wiley: Hoboken, NJ, USA, 2021; pp. 281–299. [CrossRef]
5. Abioye, S.O.; Oyedele, L.O.; Akanbi, L.; Ajayi, A.; Davila Delgado, J.M.; Bilal, M.; Akinade, O.O.; Ahmed, A. Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges. *J. Build. Eng.* **2021**, *44*, 103299. [CrossRef]
6. Ernstsen, S.N.; Whyte, J.; Thuesen, C.; Maier, A. How innovation champions frame the future: Three visions for digital transformation of construction. *J. Constr. Eng. Manag.* **2021**, *147*, 05020022. [CrossRef]
7. Maskuriy, R.; Selamat, A.; Ali, K.N.; Maresova, P.; Krejcar, O. Industry 4.0 for the construction industry-how ready is the industry? *Appl. Sci.* **2019**, *9*, 2819. [CrossRef]
8. Sawhney, A.; Riley, M.; Irizarry, J. *The Next Revolution in The Construction Industry (Construction 4.0)*, 1st ed.; Routledge: London, UK, 2020.
9. Eastman, C.; Eastman, C.M.; Teicholz, P.; Sacks, R. *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*; John Wiley & Sons: Hoboken, NJ, USA, 2011.
10. Arroteia, V.A.; Amarul, G.G.D.; Kikuti, S.Z.; Melhado, S.B. BIM Knowledge Assessment: An Overview among Professionals, in Architecture in the Age of the 4th Industrial Revolution, Porto, Portugal. Available online: https://www.researchgate.net/publication/335870709_BIM_knowledge_assessment_an_overview_among_professionals (accessed on 21 July 2024).
11. Toyin, J.; Mewomo, M. Assessing the innovative skills and competencies required of construction management graduates. *Organ. Technol. Manag. Constr. Int. J.* **2023**, *15*, 90–106. [CrossRef]
12. Hamma-adama, M.; Kouider, T. Comparative Analysis of BIM Adoption Efforts by Developed Countries as Precedent for New Adopter Countries. *Curr. J. Appl. Sci. Technol.* **2019**, *36*, 1–25. [CrossRef]
13. Feng, Y.; Pienaar, J.; Zhong, Y. Educational attainment and job requirements: Exploring the gaps for construction graduates in Australia from an industry point of view. *J. Prof. Issues Eng. Educ. Pract.* **2015**, *141*, 06015001. [CrossRef]
14. Forsythe, P.; Jupp, J.; Sawhney, A. Building information modelling in tertiary construction project management education: A programme-wide implementation strategy. *J. Educ. Built Environ.* **2013**, *8*, 16–34. [CrossRef]
15. Rui, Y.; Yaik-Wah, L.; Siang, T.C. Construction Project Management Based on Building Information Modeling (BIM). *Civ. Eng. Archit.* **2021**, *9*, 2055–2061. [CrossRef]
16. Wang, L.; Xueyuan, Y.; Fan, B.; Jin, R.; Yang, T.; Kapogiannis, G. Incorporating BIM in the Final Semester Undergraduate Project of Construction Management—A Case Study in Fuzhou University. *KSCE J. Civ. Eng.* **2020**, *24*, 2403–2418. [CrossRef]
17. Toyin, J.O.; Mewomo, M.C. *Critical Review of the iMpacts of Successful BIM Technology Application on Construction Projects (Construction in 5D: Deconstruction, Digitalization, Disruption, Disaster, Development)*; Springer International Publishing: Berlin/Heidelberg, Germany, 2023.
18. Dossick, C.S.; Lee, N.; Foleyk, S. Building Information Modeling in Graduate Construction Engineering and Management Education. In *Computing in Civil and Building Engineering*; American Society of Civil Engineers: Reston, VA, USA, 2014. [CrossRef]
19. Kolarić, S.; Mandičák, T.; Vukomanović, M.; Mésároš, P. BIM training in construction management educational practices in dateCroatia and Slovakia. In Proceedings of the Creative Construction Conference, Ljubljana, Slovenia, 30 June–3 July 2018. [CrossRef]
20. Gu, N.; London, K. Understanding and facilitating BIM adoption in the AEC industry. *Autom. Constr.* **2010**, *19*, 988–999. [CrossRef]
21. Gardner, J.; Hosseini, M.R.; Rameezdeen, R.; Chileshe, N. Building information modelling (BIM) education in South Australia: Industry needs. In Proceedings of the 5th International Conference on Engineering, Project, and Production Management (EPPM 2014), Port Elizabeth, South Africa, 26–28 November 2014; p. 293.
22. Zhao, D.; McCoy, A.P.; Bulbul, T.; Fiori, C.M.; Nikkhoo, P. Building Collaborative Construction Skills through BIM-integrated Learning Environment. *Int. J. Constr. Educ. Res.* **2015**, *11*, 120–197. [CrossRef]
23. Buscemi, L.; Debs, L.; Zimpfer, M. WIP: Teaching of emerging technology in construction workforce development programs. In Proceedings of the 2022 IEEE Frontiers in Education Conference (FIE), Uppasala, Sweden, 29 November 2022; pp. 1–5. [CrossRef]

24. Abdirad, H.; Dossick, C.S. BIM curriculum design in architecture, engineering, and construction education: A systematic review. *J. Inf. Technol. Constr. (ITcon)* **2016**, *21*, 250–271. Available online: http://www.itcon.org/2016/17 (accessed on 7 June 2023).
25. Eriqat, M.O.; Sweis, R.J.; Sweis, G.J. The challenges of adopting emerging technologies in the AEC industry a literature review and bibliometric analysis. *Constr. Innov.* **2024**. *ahead-of-print*. [CrossRef]
26. Ghosh, A.; Parrish, K.; Chasey, A. From BIM to Collaboration: A Proposed Integrated Construction curriculum. In Proceedings of the 2013 ASEE Annual Conference & Exposition, Atlanta, Georgia, 23–26 June 2013. [CrossRef]
27. Puolitaival, T.; Kestle, L. Teaching and learning in AEC education—The building information modelling factor. *J. Inf. Technol. Constr.* **2018**, *23*, 195–214. Available online: http://www.itcon.org/2018/10 (accessed on 21 July 2024).
28. Mutis, I.; Fruchter, R.; Menassa, C.C. *Advances in BIM Education (Transforming Engineering Education: Innovative Computer-Mediated Learning Technologies)*; American Society of Civil Engineers: Reston, Virginia, 2018. (In English)
29. Agyemang, D.Y.; Fong, P. Towards Desirable Skill-Set Acquisition by Construction Management Students: A Systematic Review. In Proceedings of the International Conference on Intellectual Capital, Knowledge Management & Organizational Learning, Sydney, Australia, 18 November 2019; pp. 397–406. (In English).
30. Witt, E.; Kähkönen, K. BIM-enabled education: A systematic literature review. In *Proceedings of the 10th Nordic Conference on Construction Economics and Organization*; Emerald Publishing Limited: Leeds, UK, 2019; Volume 2, pp. 261–269. [CrossRef]
31. Olowa, T.O.; Witt, E.; Lill, I. BIM for construction education: Initial findings from a literature review. In *Proceedings of the 10th Nordic Conference on Construction Economics and Organization*; Emerald Publishing Limited: Leeds, UK, 2019; Volume 2, pp. 305–313. [CrossRef]
32. Besné, A.; Pérez, M.Á.; Necchi, S.; Peña, E.; Fonseca, D.; Navarro, I.; Redondo, E. A systematic review of current strategies and methods for BIM implementation in the academic field. *Appl. Sci.* **2021**, *11*, 5530. [CrossRef]
33. Raza, M.S.; Tayeh, B.A.; Abu Aisheh, Y.I.; Maglad, A.M. Potential features of building information modeling (BIM) for application of project management knowledge areas in the construction industry. *Heliyon* **2023**, *9*, e19697. [CrossRef]
34. Besiktepe, D.; Sparkling, A.; Debs, L.; Manuel, R. Digital Technology Applications in Construction Education: A Systematic Review of Methodological Pluralism. *Int. J. Constr. Educ. Res.* **2024**, *20*, 421–443. [CrossRef]
35. Bearman, M.; Smith, C.D.; Carbone, A.; Slade, S.; Baik, C.; Hughes-Warrington, M.; Neumann, D.L. Systematic review methodology in higher education. *High. Educ. Res. Dev.* **2012**, *31*, 625–640. [CrossRef]
36. Kitchenham, B.; Charters, S. *Guidelines for Performing Systematic Literature Reviews in Software Engineering*; Version 2.3, EBSE Technical Report EBSE-2007-01; University of Durham: Durham, UK, 2007; Available online: https://www.researchgate.net/publication/258968007 (accessed on 21 July 2024).
37. Suryodiningrat, S.P.; Ramadhan, A.; Prabowo, H.; Santoso, H.B.; Hirashima, T. Mixed reality systems in education: A systematic literature review. *J. Comput. Educ.* **2023**, *11*, 855–878. [CrossRef]
38. Page, M.J.; Moher, D.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E. PRISMA 2020 explanation and elaboration: Updated guidance and exemplars for reporting systematic reviews. *BMJ* **2021**, *372*, n160. [CrossRef] [PubMed]
39. Lockwood, C.; Porrit, K.; Munn, Z.; Rittenmeyer, L.; Salmond, S.; Bjerrum, M.; Loveday, H.; Carrier, J.; Stannard, D. *Systematic Reviews of Qualitative Evidence; JBI Manual for Evidence Synthesis*; JBI: North Adelaide, Australia, 2024. [CrossRef]
40. Mark Petticrew, H.R. *Systematic Reviews in the Social Sciences: A Practical Guide*; Wiley: Hoboken, NJ, USA, 2006. [CrossRef]
41. Munn, Z.; Porritt, K.; Lockwood, C.; Aromataris, E.; Pearson, A. Establishing confidence in the output of qualitative research synthesis: The ConQual approach. *BMC Med. Res. Methodol.* **2014**, *14*, 108. [CrossRef]
42. Dang, H.; Adhikari, S.; Anderson, A. Teaching Building Information Modeling Courses in Construction Programs. In Proceedings of the Computing in Civil Engineering, Corvalis, OR, USA, 25–28 June 2023. [CrossRef]
43. Posillico, J.J.; Edwards, D.J.; Roberts, C.; Shelbourn, M. A conceptual construction management curriculum model grounded in scientometric analysis. *Eng. Constr. Archit. Manag.* **2023**, *30*, 4143–4170. [CrossRef]
44. Wetzel, E.M.; Farrow, C.B. Active learning in construction management education: Faculty perceptions of engagement and learning. *Int. J. Constr. Manag.* **2023**, *23*, 1417–1425. [CrossRef]
45. Wang, T.; Feng, J. Linking BIM Definition, BIM Capability Maturity, and Integrated Project Delivery in the AECO Industry: The Influences of BIM Diffusion and Moral Hazard. *J. Urban Plan. Dev.* **2022**, *148*, 04022025. [CrossRef]
46. Böes, J.S.; Barros Neto, J.d.P.; Lima, M.M.X.d. BIM maturity model for higher education institutions. *Ambiente Construído* **2021**, *21*, 131–150. [CrossRef]
47. Wang, L.; Huang, M.; Zhang, X.; Jin, R.; Yang, T. Review of BIM adoption in the higher education of AEC disciplines. *J. Civ. Eng. Educ.* **2020**, *146*, 06020001. [CrossRef]
48. Chen, K.; Lu, W.; Wang, J. University–industry collaboration for BIM education: Lessons learned from a case study. *Ind. High. Educ.* **2020**, *34*, 401–409. [CrossRef]
49. Huang, Y. A Review of Approaches and Challenges of BIM Education in Construction Management. *J. Civ. Eng. Archit.* **2018**, *12*, 401–407. [CrossRef]

50. Huang, Y. Developing a Modular Advanced BIM Course in Construction Management. *J. Build. Constr. Plan. Res.* **2018**, *6*, 198–214. [CrossRef]
51. Singh, S.S.V. Assessing students' sentiments towards the use of a Building Information Modelling (BIM) learning platform in a construction project management course. *Eur. J. Eng. Educ.* **2018**, *43*, 492–506. [CrossRef]
52. Zhang, J.; Xie, H.; Li, H. Competency-based knowledge integration of BIM capstone in construction engineering and management education. *Int. J. Eng. Educ.* **2017**, *33*, 2020–2032.
53. Kelly, M.; Costello, M.; Nicholson, G.; O'Connor, J. A collaborative academia-industry approach to developing a higher education programme in Building Information Modelling. *Int. J. 3-D Inf. Model. (IJ3DIM)* **2016**, *5*, 39–54. [CrossRef]
54. Lee, N.; Reeder, L.S. A Preliminary Study on Upper-Level Building Information Modeling Education for Construction Management Students. In Proceedings of the ASEE Annual Conference & Exposition, New Orleans, LA, USA, 26–29 June 2016. [CrossRef]
55. Bozoglu, J. Collaboration and coordination learning modules for BIM education. *J. Inf. Technol. Constr.* **2016**, *21*, 152–163. Available online: http://www.itcon.org/2016/10 (accessed on 10 April 2023).
56. Zhang, J.; Xie, H.; Li, H. Exploring the cognitive structure and quality elements: Building information modeling education in civil engineering and management. *Int. J. Eng. Educ.* **2016**, *32*, 1679–1690.
57. Adamu, Z.; Thorpe, T. How universities are teaching BIM: A review and case study from the UK. *J. Inf. Technol. Constr.* **2016**, *21*, 119–139. Available online: http://www.itcon.org/2016/8 (accessed on 20 April 2023).
58. Gier, D.M.; Ms, P. Integrating Building Information Modeling (BIM) into core courses within a curriculum: A case study. *Int. J. Eng. Res. Gen. Sci.* **2015**, *3*, 528–543.
59. Wang, L.; Leite, F. Process-Oriented Approach of Teaching Building Information Modeling in Construction Management. *J. Prof. Issues Eng. Educ. Pract.* **2014**, *140*, 04014004. [CrossRef]
60. Sacks, R.; Pikas, E. Building information modeling education for construction engineering and management. I: Industry requirements, state of the art, and gap analysis. *J. Constr. Eng. Manag.* **2013**, *139*, 04013016. [CrossRef]
61. Benhart, B.L.; Shaurette, M. Establishing New Graduate Competencies: Purdue University's Construction Management Curriculum Restructuring. *Int. J. Constr. Educ. Res.* **2013**, *10*, 19–38. [CrossRef]
62. Lee, N.; Dossick, C.S.; Foley, S.P. Guideline for Building Information Modeling in Construction Engineering and Management Education. *J. Prof. Issues Eng. Educ. Pract.* **2013**, *139*, 266–274. [CrossRef]
63. Forgues, D.; Becerik-Gerber, B. Integrated project delivery and building information modeling: Redefining the relationship between education and practice. *Int. J. Des. Educ.* **2013**, *6*, 47–56. [CrossRef]
64. Peterson, F.; Hartmann, T.; Fruchter, R.; Fischer, M. Teaching construction project management with BIM support: Experience and lessons learned. *Autom. Constr.* **2011**, *20*, 115–125. [CrossRef]
65. Maria Bernardete Barison, E.T.S. Review and analysis of current strategies for planning a bim curriculum. In Proceedings of the CIB W78 2010 27th International Conference, Cairo, Egypt, 16–19 November 2010; Available online: https://www.researchgate.net/publication/267690996 (accessed on 20 October 2024).
66. Olowa, T.; Witt, E.; Lill, I. BIM for Construction Education in Nigeria. In Proceedings of the Nordic Conference on Construction Economics and Organization, Copenhagen, Denmark, 16–20 May 2022. [CrossRef]
67. Adhikari, S.; Langar, S.; Mosier, R. Industry-Academia collaboration on 4D BIM modeling to enhance the understanding of Construction Scheduling. In Proceedings of the 2022 ASEE Annual Conference & Exposition, Minneapolis, MN, USA, 26–29 June 2022; Available online: https://strategy.asee.org/41330 (accessed on 20 October 2024).
68. Dossick, C.S.; Hochstatter, K.; Borhani, A.; Pratama, L. Preparing Students for Construction Management Technology Curriculum. In Proceedings of the 2022 ASEE Annual Conference & Exposition, Minneapolis, MN, USA, 26–29 June 2022.
69. Adhikari, S.; Meadati, P.; Baek, M. The implementation of bim application in university teaching: Case study of construction management program. In Proceedings of the ASEE Virtual Annual Conference, ASEE, Virtual Online, 22 June 2020. [CrossRef]
70. Mesaroš, P.; Mandičak, T.; Vukomanović, M.; Kolarić, S. Comparison of BIM education process in construction management field at Technical University of Košice and University of Zagreb. In Proceedings of the 2018 16th International Conference on Emerging eLearning Technologies and Applications (ICETA), Stary Smokovec, Slovakia, 15–16 November 2018; pp. 379–384. [CrossRef]
71. Huang, Y. Introducing an Advanced Building Information Modeling Course in Construction Management Programs. In Proceedings of the 2017 ASEE Annual Conference & Exposition, Columbus, OH, USA, 24 June 2017.
72. Yilei, H. Incorporating Building Information Modeling in Existing Courses: A Systematic Framework for Undergraduate Construction Management Programs. In Proceedings of the 2016 ASEE Annual Conference & Exposition, New Orleans, LO, USA, 26 June 2016; Available online: https://peer.asee.org/25650 (accessed on 21 July 2024).
73. Liu, R.; Hatipkarasulu, Y. Introducing building information modeling course into a newly developed construction program with various student backgrounds. In Proceedings of the 2014 ASEE Annual Conference & Exposition, Indianapolis, Indiana, 15 June 2014; pp. 24–806.

74. Gosh, S.; Bhattacharjee, S. A Systematic Review of Research Papers on Construction Education and Research: 2000–2011. In Proceedings of the 49th ASC Annual International Conference Proceedings, San Luis Obispo, CA, USA, 10–13 April 2013; pp. 1–11.
75. Clevenger, C.M.; Ozbek, M.; Glick, S.; Porter, D. Integrating BIM into Construction Management Education. Available online: https://www.academia.edu/7386747/Integrating_BIM_into_Construction_Management_Education (accessed on 21 July 2024).
76. Aliu, J.; Aigbavboa, C. Reviewing the trends of construction education research in the last decade: A bibliometric analysis. *Int. J. Constr. Manag.* **2023**, *23*, 1571–1580. [CrossRef]
77. Obi, L.I.; Omotayo, T.; Ekundayo, D.; Oyetunji, A.K. Enhancing BIM competencies of built environment undergraduates students using a problem-based learning and network analysis approach. *Smart Sustain. Built Environ.* **2022**, *13*, 217–238. [CrossRef]
78. Wang, L.; Huang, M.; Zhang, X.; Yan, X.; Jin, R.; Wanatowski, D.; Cheshmehzangi, A.; Chohan, N. Incorporating BIM into the upper-division curriculum of construction engineering and management. *Eur. J. Eng. Educ.* **2022**, *48*, 482–501. [CrossRef]
79. Hu, M. BIM-enabled pedagogy approach: Using BIM as an instructional tool in technology courses. *J. Prof. Issues Eng. Educ. Pract.* **2019**, *145*, 05018017. [CrossRef]
80. Francisco Zamora-Polo, A.L.; Sánchez-Martín, J. Conceptual Framework for the Use of Building Information Modeling in Engineering Education. *Int. J. Eng. Educ.* **2019**, *35*, 744–755. Available online: https://hdl.handle.net/11441/93778 (accessed on 16 July 2024).
81. Leite, F. Project-based learning in a building information modeling for construction management course. *J. Inf. Technol. Constr.* **2016**, *21*, 164–176. Available online: https://www.itcon.org/2016/11 (accessed on 20 April 2023).
82. Charlesraj, V.P.C.; Sawhney, A.; Singh, M.M.; Sreekumar, A. BIM Studio—An Immersive Curricular Tool for Construction Project Management Education. In Proceedings of the 32nd ISARC International Symposium on Automation and Robotics in Construction, Oulu, Finland, 15–18 June 2015. [CrossRef]
83. Park, C.S.; Le, Q.T.; Pedro, A.; Lim, C.R. Interactive Building Anatomy Modeling for Experiential Building Construction Education. *J. Prof. Issues Eng. Educ. Pract.* **2015**, *142*, 04015019. [CrossRef]
84. Kim, J.J. Use of BIM for Effective Visualization Teaching Approach in Construction Education. *J. Prof. Issues Eng. Educ. Pract.* **2015**, *138*, 214–223. [CrossRef]
85. Kristen Parrish, A.G. Implementing a Vertically Integrated BIMCurriculum in an Undergraduate ConstructionManagement Program. *Int. J. Constr. Educ. Res.* **2014**, *11*, 121–139. [CrossRef]
86. Díaz, B.; Han, K. BIM: A Bridge to Promote Industry-Academic Partnership in Construction Engineering. In Proceedings of the 2022 ASEE Annual Conference & Exposition, Minneapolis, MN, USA, 26–29 June 2022.
87. Sassine, R.; Eslahi, M.; El Meouche, R. Collaborative BIM for Construction Engineering Students. In *Advances in Building Information Modeling*; Springer International Publishing: Cham, Switzerland, 2022; pp. 115–131.
88. Olowa, T.; Witt, E.; Lill, I. Evaluating Construction Education Interventions. In Proceedings of the International Conference on Interactive Collaborative Learning, Tallinn, Estonia, 23–25 September 2021; pp. 497–508. [CrossRef]
89. Adhikari, S.; Meadati, P. Pedagogy to Teach BIM in Construction Management Curriculum. In Proceedings of the ASEE Annual Conference and Exposition, Conference Proceedings, Virtual Online, 26–29 July 2021. [CrossRef]
90. Suh, K.S.S.I.C.M.F.a.M.J. Beyond BIM: The Evolution of an IT for Construction Course. In Proceedings of the Construction Research Congress 2018, New Orleans, LA, USA, 2–4 April 2018; pp. 54–64. [CrossRef]
91. Toyin, J.O.; Mewomo, M.C. Building information modelling core competencies expected of construction management graduates: In Proceedings of the 38th Annual ARCOM Conference, Association of Researchers in Construction Management, Glasgow, UK, 5–7 September 2022.
92. Keung, C.C.W.; Yiu, T.W.; Feng, Z. Building Information Modeling Education for Quantity Surveyors in Hong Kong: Current States, Education Gaps, and Challenges. *Int. J. Constr. Educ. Res.* **2023**, *19*, 259–275. [CrossRef]
93. lot Tanko, B.; Mbugua, L. BIM education in higher learning institutions: A scientometric review and the Malaysia perspective. *Int. J. Built Environ. Sustain.* **2022**, *9*, 23–37. [CrossRef]
94. Sampaio, A.Z. BIM Education Required in Construction Industry. In *Sustainability and Automation in Smart Constructions. Advances in Science, Technology & Innovation*; Springer: Cham, Switzerland, 2021; pp. 3–9. Available online: https://link.springer.com/chapter/10.1007/978-3-030-35533-3_1 (accessed on 21 July 2024).
95. Tayeh, R.; Issa, R.R.A. Developing Construction Information Systems Courses Based on Collaboration between Industry and Academia. *J. Archit. Eng.* **2021**, *27*, 04021016. [CrossRef]
96. Mandičák, T.; Mésároš, P.; Behún, M.; Behúnová, A. Development of Digital and Managerial Competencies and BIM Technology Skills in Construction Project Management. In *New Approaches in Management of Smart Manufacturing Systems: Knowledge and Practice*; Knapcikova, L., Balog, M., Peraković, D., Periša, M., Eds.; Springer International Publishing: Cham, Switzerland, 2020; pp. 159–175.
97. Wu, W.; Mayo, G.; McCuen, T.L.; Issa, R.R.A.; Smith, D.K. Building Information Modeling Body of Knowledge. I: Background, Framework, and Initial Development. *J. Constr. Eng. Manag.* **2018**, *144*, 04018065. [CrossRef]

98. Wu, W.; Mayo, G.; McCuen, T.L.; Issa, R.R.A.; Smith, D.K. Building Information Modeling Body of Knowledge. II: Consensus Building and Use Cases. *J. Constr. Eng. Manag.* **2018**, *144*, 04018066. [CrossRef]
99. Zhang, J.; Wu, W.; Li, H. Enhancing Building Information Modeling Competency among Civil Engineering and Management Students with Team-Based Learning. *J. Prof. Issues Eng. Educ. Pract.* **2018**, *144*, 05018001. [CrossRef]
100. Turmo, J.; Lozano, J.A. Modern learning strategy for teaching about construction management in Poland. In Proceedings of the International Conference on Civil Engineering Education, Barcelona, Spain, 5–8 September 2018.
101. Lucas, J.D. Identifying Learning Objectives by Seeking a Balance between Student and Industry Expectations for Technology Exposure in Construction Education. *J. Prof. Issues Eng. Educ. Pract.* **2017**, *143*, 05016013. [CrossRef]
102. Shelbourn, M.; Macdonald, J.; McCuen, T.; Lee, S. Students' perceptions of BIM education in the higher education sector: A UK and US perspective. *Ind. High. Educ.* **2017**, *31*, 293–304. [CrossRef]
103. Santos, E.T.; Bariso, M.B. A Tool for Assisting Teachers in Planning BIM Courses. In Proceedings of the Computing in Civil and Building Engineering, Orlando, FL, USA, 23–25 June 2014; pp. 2159–2166. Available online: https://ascelibrary.org/doi/abs/10.1061/9780784413616.268 (accessed on 21 July 2024).
104. Mesaros, P.; Mandicak, T.; Behunova, A.; Smetankova, J.; Krajnikova, K. Impact of BIM Technology on Development of Digital and Managerial Competencies of Project Managers in Construction Industry. In Proceedings of the 4th EAI International Conference on Management of Manufacturing Systems, Krynica Zdroj, Poland, 8–10 October 2019; Springer International Publishing: Cham, Switzerland, 2020; pp. 175–184. [CrossRef]
105. Shelbourn, M.; Macdonald, J.; Mills, J. Developing an International Framework for BIM Education in the HE Sector. In Proceedings of the 10th BIM Academic Symposium & Job Task Analysis Review, Orlando, FL, USA, 4–5 April 2016.
106. Olatunji, O.A. Promoting student commitment to BIM in construction education. *Eng. Constr. Archit. Manag.* **2019**, *26*, 1240–1260. [CrossRef]
107. Mills, J.; MacDonald, J. An IPD approach to construction education. *Australas. J. Constr. Econ. Build.* **2013**, *13*, 93–103.
108. Arashpour, M.; Aranda-Mena, G. Curriculum renewal in architecture, engineering, and construction education: Visualizing building information modeling via augmented reality. In Proceedings of the International Structural Engineering and Construction Conference 2017: Resilient Structures and Sustainable Construction, Valencia, Spain, 24–29 July 2017. [CrossRef]
109. Dawkins, P.; Hurley, P.; Noonan, P. Rethinking and Revitalising Tertiary Education in Australia. Mitchell Institute, Melbourne. 2019. Available online: www.mitchellinstitute.org.au (accessed on 10 April 2023).
110. Jayawickrama, T.; Abdelaal, S.; Abadia, R. Using online learning environments to address digital literacy competencies of construction management graduates. In Proceedings of the ICCE 2020—28th International Conference on Computers in Education, Proceedings, Online, 23–27 November 2020; Volume 1, pp. 670–679.
111. Guo, B.H.W.; Gonzalez, V.A.; Puolitaival, T.; Enegbuma, W.; Zou, Y. Bridging the gap between building information modelling education and practice: A competency-based education perspective. *Int. J. Constr. Manag.* **2022**, *23*, 2558–2569. [CrossRef]
112. Casasayas, O.; Hosseini, M.R.; Edwards, D.; Shuchi, S.; Chowdhury, M. Integrating BIM in higher education programs: Barriers and remedial solutions in Australia. *J. Archit. Eng.* **2021**, *27*, 05020010. [CrossRef]
113. Vaz-Serra, P.; Mitcheltree, H. Understanding the Key Master of Construction Project Management Graduate Competencies Required to Meet Industry Needs in Australia. *Int. J. Constr. Educ. Res.* **2020**, *17*, 222–241. [CrossRef]
114. Puolitaival, T.; Forsythe, P. Practical challenges of BIM education. *Struct. Surv.* **2016**, *34*, 351–366. [CrossRef]
115. Succar, B.; Sher, W. *A Competency Knowledge-Base for BIM Learning*; Australasian Journal of Construction Economics and Building-Conference Series; UTS ePress: Ultimo, Australia, 2014; Volume 2, pp. 1–10. [CrossRef]
116. Hon, C.; Utiome, E.; Drogemuller, R.; Owen, R.; Nepal, M.; Gray, J.; Coffey, V. Gearing up academics for collaborative Building Information Modelling (BIM) education. In Proceedings of the 2015 International Conference on Innovative Production and Construction 2015 (IPC 2015), Perth, Australia, 28–31 July 2015; pp. 23–26.
117. Shuchi, S.; Chowdhury, M.; Martek, I.; Hosseini, M.R.; Rahnamayiezekavat, P.; Jupp, J.R. *BIM Education at Australian Universities: 2020 Insights*; Australia Deakin University: Geelong, Australia, 2021.
118. Huang, Y. Developing a Three-Level Framework for Building Information Modeling Education in Construction Management. *Univers. J. Educ. Res.* **2018**, *6*, 1991–2000. [CrossRef]
119. Sacks, R.; Hassan, O. Building information modeling education for construction engineering and management. II: Procedures and Implementation Case Study. *J. Constr. Eng. Manag.* **2013**, *139*, 04013016. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.