

Trends of BIM integration in construction education: A bibliometric-based visualization analysis

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ARTICLE INFO	ABSTRACT
<p><i>Article history:</i> Received September 28, 2024 Received in revised form Dec. 30, 2024 Accepted January 15, 2025 Available online April 01, 2025</p> <p><i>Keywords:</i> Bibliometric BIM Construction education Integration Trend</p> <p>*Corresponding author: Tutin Aryanti Department of Architectural Engineering Education, Universitas Pendidikan Indonesia Email: tutin@upi.edu ORCID: https://orcid.org/0000-0001-6986-0680</p>	<p><i>Building Information Modeling (BIM) has profoundly altered the construction industry, prompting an increased focus on integrating BIM into academic curricula related to construction disciplines. Nevertheless, limited research has explored the global trends surrounding the integration of BIM within construction education. This study uses bibliometric analysis to identify and critically assess the prominent topics and trends in BIM education research over the last decade. Drawing from 462 bibliometric records from the Scopus database, the analysis utilized VOSviewer to visualize and assess patterns in co-authorship, co-word, and co-citation. The results indicate that the United States, China, and the United Kingdom have made the most significant strides in BIM education research, with strong collaborative ties observed between geographically proximate countries, such as China-Malaysia and USA-Brazil. The analysis of keyword co-occurrences suggests that BIM educational research is predominantly concentrated in civil engineering, construction management, and architecture. Furthermore, there is a discernable shift from traditional, discipline-specific teaching approaches towards interdisciplinary, collaborative, and problem-based learning paradigms incorporating advanced virtual technologies. Key emerging themes, such as “virtual reality,” “digital twins,” and “virtual learning environments,” underscore the evolving nature of BIM education. The study emphasizes the necessity of sustained advancements in BIM education, with particular emphasis on interdisciplinary collaboration, technological integration, and pedagogical innovation to meet the dynamic demands of the construction industry.</i></p>

Introduction

BIM has become an innovative technology within the global construction industry, fundamentally changing how construction projects are conceived, designed, and executed (Abdelhai 2022). This technological shift has redefined industry practices and greatly influenced the workforce requirement for skilled construction professionals and delineated roles. The dynamic nature of BIM technology demands a wide range

of technical and managerial competencies, yet developing training programs and acquiring these skills continue to pose significant challenges for effective BIM adoption. Both industry stakeholders and academic institutions acknowledge the critical importance of BIM integration into educational (Abdirad and Dossick 2016; Wang et al. 2023). A growing body of civil engineering and construction education research has emphasized the increasing inclusion of BIM-related content into academic programs (Chen et al. 2019; Zheng, Chen, and Lu 2019). The



incorporation of BIM into university-level curricula not only reduces the costs associated with industry adoption but also improves the career prospects of graduates within the construction industry.

Higher education institutions (HEIs) are increasingly incorporating BIM into their curricula to foster innovation, promote interdisciplinary collaboration, and enhance student project management skills. This guarantees that graduates possess the competencies required to address the evolving needs of the construction industry (Ismail et al. 2019). Despite these initiatives, there are still difficulties integrating BIM education, mainly due to the lack of standardized BIM expertise, which complicates the establishment of consistent curriculum content (Zhang, Schmidt, and Li 2016; Casasayas et al. 2021; Oyesode et al. 2023). Furthermore, because the construction industry is rapidly evolving, students must develop technical proficiency and the ability to navigate and leverage emerging technologies (Casini 2021). Thus, HEIs face the complex task of designing curricula that address current BIM technologies and anticipate future developments to meet industry needs (Govender et al. 2022). This forward-thinking approach is essential for cultivating a workforce capable of driving innovation and improving efficiency. However, it also presents challenges in fostering a mentality of continuous learning and adaptation among students.

Although several studies have examined how HEIs incorporate BIM into their construction-related programs, a comprehensive analysis of the global trends in BIM integration within these curricula remains scarce. By providing an in-depth bibliometric analysis of trends in BIM integration across HEIs, this study seeks to close that knowledge gap. Precisely, this study will (1) map the evolution of BIM integration in HEI curricula over the past decade, (2) examine the global distribution of research outputs in the field, (3) visualize the collaborative networks among researchers, and (4) synthesize existing knowledge on the integration of BIM in AEC curricula. By uncovering these trends, this study offers insightful information to educators and researchers, assisting them in evaluating current BIM curricula and making informed decisions for future developments. Aligning academic training with industry demands and technological advancements will ensure students acquire the

digital skills necessary to thrive in the ever-evolving construction industry (Tang, Jin, and Fang 2015; Delgado et al. 2020).

Methods

This research performs a bibliometric analysis to examine trends in integrating BIM into construction-related higher education curricula. Using bibliometric analysis strengthens the study's rigor by objectively evaluating the literature, minimizing researcher bias, and offering valuable insights into research trends and influential contributors (Linnenluecke, Marrone, and Singh 2020).

Bibliometric data search

The bibliometric analysis commenced with formulating a comprehensive search strategy, utilizing critical BIM and construction education terms. The selection of the Scopus database is attributed to its extensive coverage of academic journals, conference proceedings, and various scholarly publications (Chadegani et al. 2013). The search query used was TITLE-ABS-KEY (“BIM” OR “Building Information Modeling”) AND (“Higher Education” OR “Education”) OR (“Curriculum” OR “Students”). This query resulted in 1,452 publications on BIM integration within higher education curricula. After applying filters for language, subject area, publication period (2018-2023), and document type (journals and conference proceedings), the dataset was refined to 661 papers. The bibliometric data were exported in CSV format for further screening and analysis.

Eligibility criteria

Additional screening was conducted to ensure the relevance of the included publications. Articles were excluded if they (1) did not directly address BIM in higher education or (2) were related to educational research within the Architecture, Engineering, and Construction (AEC) disciplines but did not emphasize BIM. After reviewing abstracts and, when necessary, the full texts, 462 publications were deemed suitable for inclusion in the final dataset. Most of the literature on BIM education is disseminated through conference proceedings, as noted by Huang (2017), further demonstrating the

prominence of conferences in this research domain.

Table 1. Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Type of document	Journal articles and conference proceedings.	Dissertations, book series, and chapter
Language	Written in english	Non-English articles
Subject area	Focused on BIM Education higher education institutions.	Educational research in the AEC disciplines but not BIM
Period	January 2018 – December 2023	Published before 2018

Bibliometric analysis

The bibliometric analysis was performed using VOSviewer version 1.6.20, a widely recognized tool for visualizing and analyzing research keywords, co-authorship networks, and co-citation patterns (Van Eck and Waltman 2010). This tool enabled the visualization of bibliometric relationships and patterns within the selected dataset. The critical evaluation metrics included yearly trends in publication output, analysis of the geographical distribution of publications, identification of collaboration patterns within the research community, analysis of the preferred journals or conferences for dissemination of BIM education research, and examining emerging research themes and identifying critical areas of interest.

Results and discussion

Year-wise distribution of publications

Figure 1 presents the annual distribution of publications about BIM integration within construction education from 2013 to 2023. Over the last decade, there has been a steady increase in publication output, peaking at 67 publications in 2020. This surge reflects the growing recognition of BIM as an indispensable tool for the construction industry, especially within the framework of Industry 4.0. However, there are notable fluctuations, such as a dip in 2017 with only 24 publications and another in 2021 with 59 publications, compared to adjacent years. The growing body of literature on BIM education highlights its importance as the construction industry increasingly adopts digital technologies to streamline project execution and improve collaboration. The upward trend in publications

can also be attributed to increased accessibility to advanced BIM technologies and the widespread integration of BIM in construction-related academic programs. This trend fuels a productive exchange of knowledge between academia and industry, which accelerates the dissemination of BIM-related innovations.

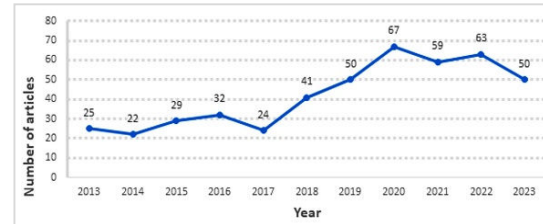


Figure 1. Yearly trend of publication

Global contribution and leading countries

An analysis of the global contributions to BIM education research indicates that the United States, China, and the United Kingdom stand out as the foremost contributors. The leading ten countries in terms of publications are the USA with 107, China with 67, and the UK with 36. Spain, Australia, Malaysia, Portugal, South Korea, Russia, and Brazil followed them. Figure 2 visualizes the co-authorship networks between countries, showing the solid collaborative ties between neighboring countries such as China-Malaysia and USA-Brazil. The USA (12 links, 24 co-authorships), China (6 links and 23 co-authorships), and the UK (13 links and 29 co-authorships) occupy central positions within the co-authorship network, with extensive international collaborations that have significantly contributed to the global advancement of BIM education.

Notably, Australia ranks fifth in publication output with 23 publications, 62% of which involved collaborations with authors from eight countries. This level of cooperation expands research networks and enhances the visibility and impact of BIM education research globally. International collaboration has proven to be a key driver of research productivity and innovation, particularly in complex, interdisciplinary technologies like BIM.

The analysis of co-authorship networks highlights the significance of global collaboration in BIM education research. Figure 2 highlights the strong connections between nations, including the USA, China, the UK, and Australia, each occupying central positions within the network.

These countries are involved in extensive international collaborations that have contributed to the global dissemination of BIM knowledge. Countries such as the USA and the UK, in particular, have demonstrated significant co-authorship with other nations, reflecting their leadership roles in BIM education research.

Collaboration on an international scale expands the breadth of research and significantly

enhances the quality of publications by incorporating varied perspectives and expertise. This trend towards global partnership is significant in BIM education, as integrating new technologies and pedagogical approaches requires exchanging knowledge and best practices across borders.

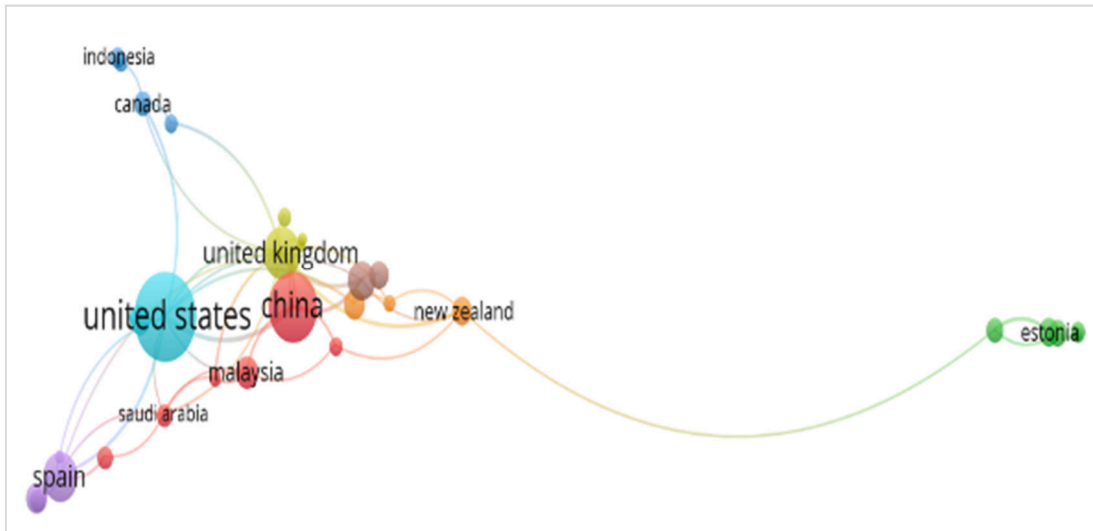


Figure 2. Co-authorship network of leading countries

Table 2. Top ten countries with the highest rates of productivity and collaboration

Country	No. of Publications	% of Publications	No. of Citations	Total Link Strength
USA	107	23	1181	24
China	67	15	355	23
UK	38	8	607	29
Spain	34	7	196	14
Australia	23	5	367	15
Malaysia	15	3	113	6
Portugal	13	3	45	2
South Korea	13	3	108	4
Russia	12	3	41	1
Brazil	11	2	32	2

Preferred journal/conferences

The bibliometric analysis of preferred journals and conferences (figure 3) highlights the ASEE Annual Conference (organized by the American Society for Engineering Education) as a leading platform for disseminating research on BIM education. The conference accounts for 35

published articles with 93 citations (table 3), emphasizing its role as a central forum for academic exchange and collaboration in BIM education research.

In addition to the ASEE Annual Conference, prominent journals such as the Journal of Information Technology in Construction (12

articles and 252 citations), the Journal of Professional Issues in Engineering Education and Practice (11 articles and 398 citations), and the International Journal of Construction Education and Research (8 publications and 122 citations) have emerged as influential platforms for BIM

research. The prominence of these journals and conferences underscores the global interest in advancing BIM education and reflects the increasing collaboration between academic researchers and industry practitioners.

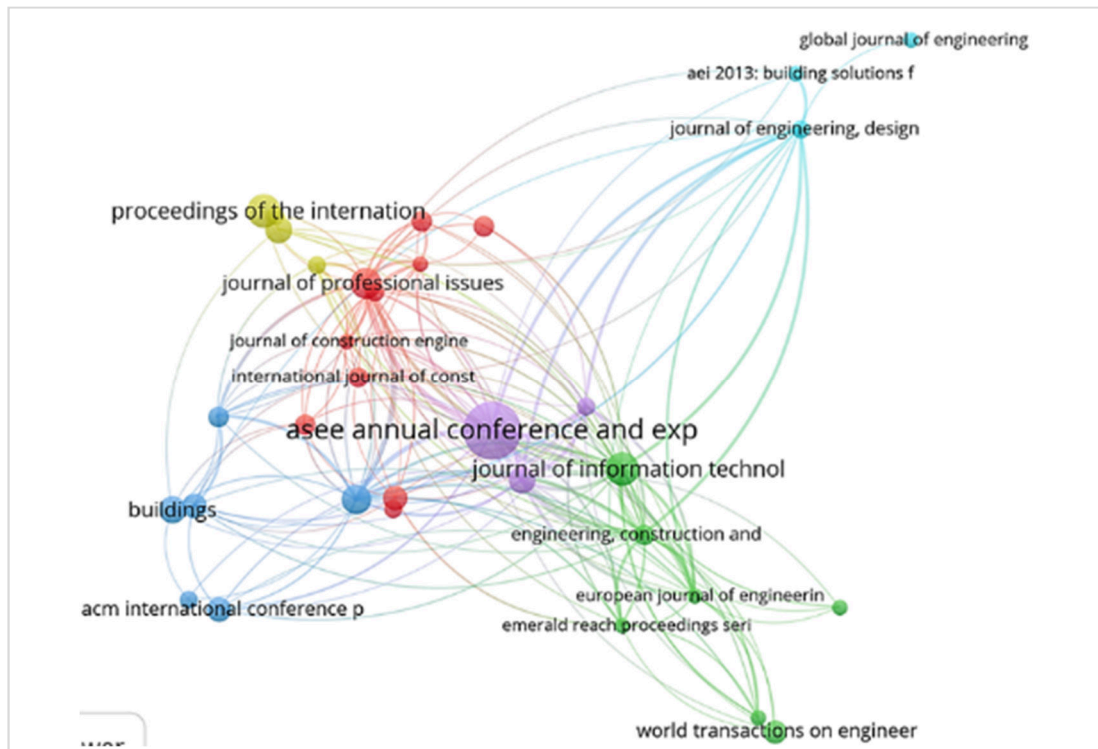


Figure 3. Network of published journals/conferences proceedings

These journals serve as vital outlets for the publication of front-line research, fostering academic debate and encouraging the exchange of ideas supporting BIM integration into higher

education curricula. Their contributions are pivotal in shaping the future of BIM education by linking academic research with practical industry applications.

Table 3. Top ten (10) most productive journals/proceedings

Journal/Conference proceedings	No. of articles	Total citations	Publishers
<i>Journal of Professional Issues in Engineering Education and Practice</i>	11	398	American Society of Civil Engineers (ASCE)
<i>Journal of Information Technology in Construction</i>	12	252	International Council for Research and Innovation in Building and Construction
<i>Engineering, Construction, and Architectural Management</i>	5	142	Emerald Publishing
<i>International Journal of Construction Education and Research</i>	8	122	Routledge
<i>International Journal of Engineering Education</i>	10	117	Tempus Publications
<i>ASEE Annual Conference</i>	35	93	American Society for Engineering Education
<i>Applied Sciences</i>	7	90	MDPI AG
<i>Journal of Civil Engineering Education</i>	5	88	American Society of Civil Engineers (ASCE)
<i>Sustainability</i>	5	74	MDPI AG

Journal/Conference proceedings	No. of articles	Total citations	Publishers
Computer Applications in Engineering Education	4	62	John Wiley and Sons Inc.

Author keyword analysis and emerging theme

The analysis of author keywords offers valuable insight into key themes and emerging trends in BIM education research. By examining the keyword occurrences, we can identify the primary focus areas and evolving patterns within the literature (Strozzi et al. 2017; Ding, Chowdhury, and Foo 2001). Across the 462 publications analyzed, 957 unique keywords were

recorded, of which 189 appeared twice and 84 were used thrice. To enhance the clarity of the analysis, keywords with similar meanings or related concepts were grouped using a thesaurus file. The keyword co-occurrence analysis identified 54 keywords that met the minimum threshold of four occurrences, reflecting the focus areas within the literature on BIM education (figure 4).

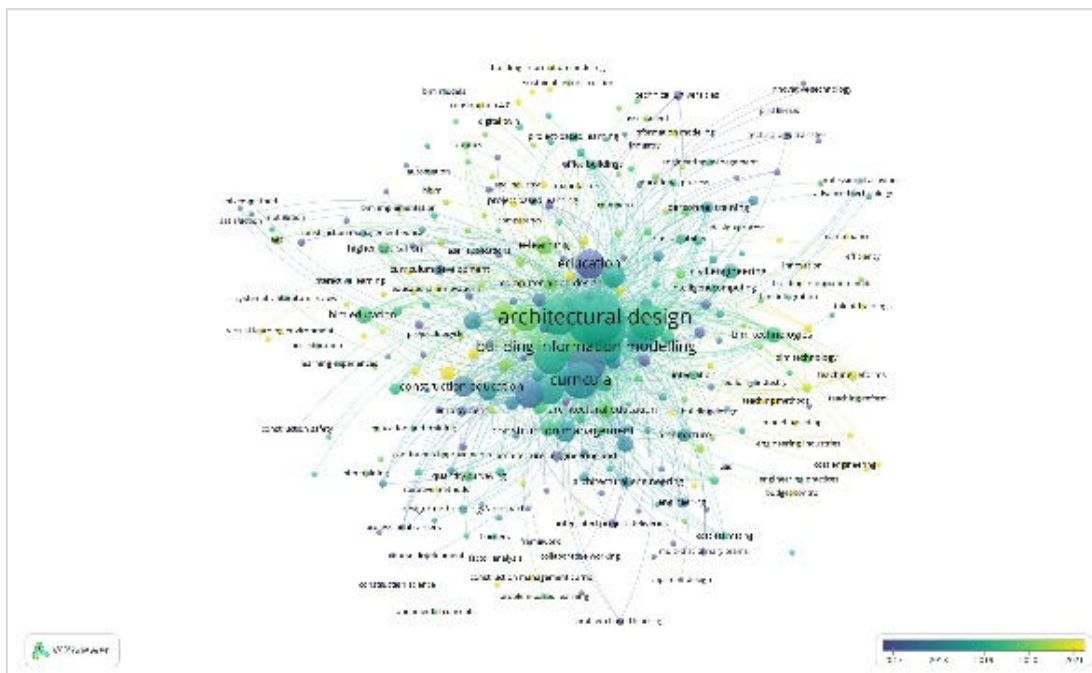


Figure 4. Author co-occurrence network

Among the most frequently occurring keywords were “architectural design” (280 occurrences), “BIM” (217 occurrences), “education” (130 occurrences), “curricula” (103 occurrences), “construction management” (70 occurrences), “Virtual realities” (22 occurrences), “BIM technologies” (23 occurrences), “architectural education (17 occurrences)”, “civil engineering (56 occurrences)”, and “digital twins.” These keywords represent the central themes in BIM education research and highlight the growing emphasis on the integration of BIM into academic programs across disciplines such as civil engineering, construction management, and architecture. The clustering of keywords showcases the multidimensional nature of BIM education. The analysis also indicates a shift from

traditional, discipline-specific pedagogical methods towards more collaborative, interdisciplinary approaches emphasizing problem-based learning and virtual technology integration. Terms such as “virtual reality,” “digital twins,” and “virtual learning environments” reflect emerging research interests and underscore the importance of technological innovations in BIM education. The integration of these technologies considerably enriches students’ educational experiences, equipping them with the necessary skills to tackle the practical challenges encountered in the industry.

The trend of BIM integration in curricula

The integration of BIM in AEC Education has seen a significant drift, with educational

frameworks and approaches continually evolving (Raad, Maya, and Dlask 2023a). The trend analysis reveals a clear trajectory from early-stage adoption focused on architectural design and construction management to more advanced themes such as sustainability, educational innovations, and emerging technologies.

Teaching the fundamentals of BIM in architectural design and construction management

The focus of initial BIM integration into curricula revolved mainly around using it to enhance design accuracy and promote collaboration in architectural education, as evident by the prominence of these keywords in the early publications. However, during the early 2010s, there was a growing recognition among scholars and educators of the immense potential of BIM to transform the construction industry. Its application expanded into broader civil engineering and construction management areas, emphasizing project planning, scheduling, and cost estimation (Jin et al. 2018). Architectural design education, traditionally reliant on two-dimensional drawings, started evolving to incorporate BIM to teach students essential skills such as three-dimensional modeling, clash detection, and visualization techniques (Wong, Wong, and Nadeem 2011; Sánchez et al. 2019). This shift connected academic knowledge with industry practice, empowering students to tackle real-world design challenges using digital tools.

Similarly, construction management programs started incorporating BIM for project planning, scheduling, and cost estimation. The early focus on construction management highlights the industry's demand for professionals with expertise in managing BIM-enabled projects (Construction 2014). The ability to simulate construction processes, optimize resource allocation, and anticipate potential issues before they occur became key learning outcomes for students in these programs. With the integration of BIM into their curricula, higher educational institutions sought to enhance the quality of AEC education by aligning it with emerging technologies and equipping graduates to meet the industry's increasing need for BIM adoption, as highlighted by Laovisutthichai, Srihiran, and Lu (2023). Wang et al. (2023) echo this sentiment, highlighting the inevitability of incorporating BIM into civil engineering education to reflect the broader industry shift toward reliance on BIM-

related processes and digital technologies to improve project outcomes and efficiency.

The emergence of BIM education and curriculum development

The growing incorporation of BIM within the construction sector has led to a heightened emphasis on formalizing BIM education and developing thorough curricula in educational research. Since 2019, there has been a notable shift from simply introducing BIM concepts to systematically integrating them into academic programs. This transition is highlighted by the emergence of keywords such as "BIM education," "higher education," and "curriculum development" in 2019. During this time, research efforts expanded to explore best practices for teaching BIM, the challenges of curriculum integration, and the development of competency frameworks for students (Raad, Maya, and Dlask 2023b; Obi et al. 2022). Higher education institutions soon recognized that effective BIM education demanded more than technical training. There emerged a need for graduates who not only possessed technical BIM skills but also understood the broader context of BIM implementation, including legal, ethical, and managerial aspects (Shahrudin, Zairul, and Haron 2021). This evolution necessitated the introduction of new modules into existing programs, delving into crucial subjects such as BIM standards, interoperability, and project life cycle management.

A significant pedagogical shift accompanied this integration. Guo et al. (2023) emphasize the importance of both stand-alone BIM courses and the integration of BIM concepts into existing courses. According to the authors, this dual approach ensures that students thoroughly understand the theoretical foundations of BIM and the practical, experiential knowledge necessary for effective application. Nevertheless, Laovisutthichai, Srihiran, and Lu (2023) contend that for a successful learning experience, it is essential to integrate BIM into the existing curriculum fully. They advocate a total reorganization instead of just adding stand-alone BIM courses.

At the same time, an increasing acknowledgment of the importance of interdisciplinary collaboration within BIM emerged, as it inherently involves multiple project stakeholders (Demirdoven 2015). As a result, curriculum development efforts increasingly

emphasized collaborative learning environments, enabling students from different disciplines to engage in BIM projects together, thereby reflecting the collaborative essence of BIM in professional practice. The focus on curriculum development also demonstrated the importance of aligning educational outcomes with industry needs.

Educational innovations, sustainability, and advanced BIM technologies

The current phase of BIM integration in construction education is characterized by the rise of educational innovations, the incorporation of sustainability concepts, and the exploration of advanced BIM technologies. These trends indicate a deepening understanding of BIM education, moving beyond foundational skills to address emerging challenges and explore potential within the industry. A key development during this time is the heightened focus on educational innovations, as evidenced by the prominence of keywords such as “educational innovations,” “teaching methods,” and “virtual learning environments.” With the rise of BIM in education, there is a growing demand for innovative pedagogical approaches that effectively engage students and enhance learning outcomes (Wu and Luo 2016).

Advanced pedagogical methodologies, including project-based learning (PBL) and the integration of virtual learning environments (VLEs), have gained prominence in BIM education. These methods provide students with hands-on experience and promote interdisciplinary collaboration by allowing them to work on real-world BIM projects in a simulated environment (Hou, Lai, and Wu 2023). In the view of Patching et al. (2024) and Obi et al. (2022), this approach enhances students’ technical skills and cultivates essential soft skills, including critical thinking, problem-solving, and collaboration, that become indispensable for achieving success in the work environment. The focus on collaboration and PBL signifies a departure from conventional teaching domain-based pedagogy to a more interdisciplinary approach involving architectural, engineering, construction, and virtual technologies.

In recent years, a significant transformation has emerged in BIM education, emphasizing the integration of sustainability principles. This shift highlights the role of BIM in advancing green building initiatives, enhancing energy

performance, and evaluating environmental impacts (Motalebi, Rashidi, and Nasiri 2022). This trend reflects the growing awareness of BIM’s role in promoting sustainable construction practices and reducing the environmental footprint of building projects. With the construction industry increasingly prioritizing sustainable practices, there is an increasing demand for professionals who can effectively leverage BIM to support green building initiatives (Maskil-Leitan, Gurevich, and Reychav 2020). This has prompted educators to acknowledge the importance of integrating sustainability modules within the curriculum. The above prepares students to address the environmental challenges currently confronting the industry.

The exploration of advanced BIM technologies, including virtual reality, augmented reality, automation, digital twins, and robotics, marks the cutting edge of BIM education. These technologies represent the next frontier in construction innovation, offering new possibilities for improving efficiency, reducing costs, and enhancing project outcomes (Rane, Choudhary, and Rane 2023). In ways that traditional approaches cannot, these technologies improve student engagement and deliver immersive learning experiences (Baxter and Hainey 2023), allowing students to visualize complex BIM models more dynamically and intuitively. The incorporation of these topics into educational curricula reflects the growing need to prepare students for a rapidly evolving industry, where the ability to work with advanced technologies will be a key differentiator in the job market.

Conclusions

The incorporation of BIM into construction education has undergone a remarkable transformation over the past decade, reflecting broader industry trends and the evolving demands of the global construction market. This study’s bibliometric analysis has illuminated several key trends, including the increasing prevalence of interdisciplinary collaboration, the integration of emerging technologies, and the adoption of innovative pedagogical approaches within higher education curricula. These advancements indicate a maturation of BIM education as it transitions

from a supplementary tool to a central component of construction-related academic programs.

One of the most notable trends is the shift from traditional, discipline-specific teaching methods toward more collaborative, interdisciplinary approaches. This shift aligns with the construction industry's demand for professionals working across multiple disciplines and leveraging BIM technologies to enhance project outcomes.

The inclusion of PBL and VLEs has further enriched the educational experience, providing students with practical, hands-on opportunities to engage with real-world BIM applications. Such pedagogical innovations are instrumental in equipping graduates to tackle challenges presented by today's construction industry.

Technological integration has also become a pivotal focus in BIM education. Advanced technologies such as virtual reality (VR), digital twins, and automation are no longer viewed as mere adjuncts to BIM but as integral components that enhance its utility and application. The increasing focus on these technologies reflects a broader trend in the construction industry, as digital transformation fundamentally alters processes for project design, execution, and management. As BIM continues to evolve, educational institutions must ensure that students are equipped with the technical expertise needed to navigate these rapidly advancing technologies.

Another critical trend is the incorporation of sustainability within BIM education. As the construction industry increasingly prioritizes environmentally responsible practices, leveraging BIM for sustainable design and construction has become a vital skill. Educators have responded by embedding sustainability-related modules into BIM curricula, ensuring that students understand how to use BIM to optimize energy performance, assess environmental impacts, and contribute to green building initiatives. This focus on sustainability is crucial for equipping the upcoming generation of construction professionals to meet the global demand for sustainable infrastructure.

Looking ahead, it is evident that ongoing advancements in automation, artificial intelligence, and other emerging technologies will significantly influence the evolution of BIM education. The incorporation of digital twins, robotics, and data-informed design methodologies is set to transform the construction industry significantly. It is imperative for educational institutions to evolve their curricula in

response to emerging trends, thereby equipping students with the essential knowledge and skills required to excel in a digitalized construction landscape that prioritizes precision, efficiency, and innovation.

Moreover, interdisciplinary collaboration will remain a cornerstone of BIM education. As BIM inherently involves coordinating multiple stakeholders' architects, engineers, construction managers, and others cross-disciplinary learning environments will be essential. Institutions should emphasize joint projects and collaborative coursework that mimic real-world construction scenarios, fostering technical competencies and the soft skills needed for effective teamwork and problem-solving.

While this study has yielded significant insights into prevailing trends and future directions in BIM education, further research is essential to assess the sustained effectiveness of the identified innovative educational approaches. Understanding the outcomes of various teaching methods will be critical for educators seeking to refine and optimize BIM curricula to meet industry demands more effectively.

BIM education is poised to be critical in shaping the construction industry's future. By embracing technological advancements, promoting interdisciplinary collaboration, and embedding sustainability into curricula, higher education institutions can ensure their graduates are well-prepared to thrive in an industry undergoing rapid digital transformation. The outcome of this study provides a strategic framework for researchers, educators, and policymakers dedicated to enhancing BIM education and, consequently, the future trajectory of the construction industry.

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Author(s) contribution

Daniel Ebo Hagan contributed to the research concepts preparation, methodologies, investigations, data analysis, visualization, articles drafting and revisions.

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