



A Scoping Review on the Relevance of Construction Management Education and Teaching Approaches in the Industry 4.0 Era

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Abstract. As the construction industry evolves rapidly in the era of Industry 4.0, there is critical to reassess and realign construction management education and teaching approaches to meet these new demands. Thus the need for research looking at the misalignment between current construction management education and the evolving demands of the Industry 4.0 era. Addressing these challenges is crucial to ensure that future professionals have the skills and competencies to excel in the evolving construction landscape. This study adopted the PRISMA model through a systematic literature review to scope relevant studies on construction education and its teaching approaches. This review addresses the current state of construction management education in Industry 4.0. The study reveals that educational institutions have actively adapted curricula, integrating emerging technologies, data analytics, sustainability practices, and soft skills. Concurrently, teaching approaches have evolved to incorporate experiential learning, interdisciplinary collaboration, and digital literacy, reflecting the multifaceted competencies required in the new industry landscape. Despite these advancements, the review identifies further research and improvement areas, emphasising continuous course quality assurance, more effective pedagogical strategies for cultivating soft skills, and stronger industry-academia collaboration. The findings underscore the importance of continuous innovation, research, and collaboration in equipping future professionals with the necessary skills and competencies to thrive in the Industry 4.0 era.

Keywords: Construction Management Education, Emerging Technologies, Industry 4.0, Teaching Approaches, Scoping Review, Skills, and Competencies

1. Introduction

The construction industry is undergoing a profound transformation, propelled by the rapid advancement of digital technologies and automation, collectively known as Industry 4.0. This era is characterised by the integration of cyber-physical systems, the Internet of Things (IoT), artificial intelligence, robotics, and advanced data analytics[1,2]. These technological advancements are revolutionising how construction projects are planned, designed, executed, and maintained, ushering in a new era of possibilities, challenges, and opportunities for construction management professionals.

With the widespread adoption of digital technologies, the construction industry is experiencing a paradigm shift that necessitates re-evaluating construction management

education and teaching approaches[3]. The role of construction management education is vital in equipping students with the knowledge, skills, and competencies needed to navigate the dynamic and complex landscape of the industry. The role of construction management education is of utmost importance in preparing students to navigate the dynamic and complex landscape of the construction industry. As the industry undergoes significant transformations driven by technological advancements and automation, it becomes crucial for educational institutions to equip students with the necessary knowledge, skills, and competencies to thrive in this evolving environment.

Construction management education is the foundation for students to develop a deep understanding of the industry's principles, practices, and processes. It provides them with a comprehensive knowledge base encompassing various aspects, including project management, construction techniques, contract administration, cost estimation, quality control, and safety protocols. This knowledge base enables students to comprehend the intricacies and complexities inherent in construction projects. Construction management education equips students with the practical skills to effectively plan, organise, and execute construction projects[4]. According to (Khatib et al., 2022), students learn how to analyse project requirements, develop detailed schedules, coordinate resources, and manage budgets. They also gain expertise in risk assessment, problem-solving, and decision-making, critical competencies for successful construction managers.

Moreover, construction management education also focuses on cultivating essential competencies beyond the industry's technical aspects. These competencies include effective communication, teamwork, leadership, negotiation, and adaptability[6]. Construction projects involve collaboration with various stakeholders, including architects, engineers, contractors, and clients. Therefore, construction management professionals must possess strong interpersonal and communication skills to navigate these diverse relationships and ensure successful project outcomes[7]. Overall, construction management education is a crucial foundation for students entering the construction industry. It equips them with the knowledge, skills, and competencies needed to understand and tackle the complexities of construction projects. By combining technical expertise, practical skills, interpersonal capabilities, and a commitment to lifelong learning, construction management education prepares students to succeed in a rapidly transforming industry[8].

It is crucial to explore the current state of construction management education and its alignment with the requirements of this transformative era. This scoping review aims to identify the status quo education and teaching approaches by comprehensively analysing existing literature. The objectives of this scoping review are multifaceted and are

1. To identify and analyse the current state of construction management education concerning the requirements of the Industry 4.0 era.
2. To examine the teaching approaches and methodologies employed in construction management education and their alignment with the demands of Industry 4.0.
3. To explore the key competencies and skills construction managers need in Industry 4.0.
4. To investigate the integration of emerging into construction management education.

By addressing these objectives, this scoping review aims to provide a comprehensive understanding of the current state of construction management education in the context of Industry 4.0. It seeks to offer valuable insights, recommendations, and strategies for enhancing construction management education to ensure graduates are well-prepared for the evolving industry landscape shaped by the fourth industrial revolution. Ultimately, this review aims to improve construction management education and guide future research and development efforts in preparing the next generation of construction management professionals.

2. Methodology

A scoping review was chosen as the method for this study because it allows for a comprehensive exploration of the research landscape, accommodates diverse study designs, identifies gaps and opportunities, facilitates knowledge translation, and contributes to the advancement of construction management education in the context of Industry 4.0[9]. By examining a broad range of literature, this review aims to provide a comprehensive analysis, identify trends and challenges, and offer recommendations for future research and improvement in educational practices. The study seeks to bridge the gap between research and practice, informing decision-making and enhancing the relevance of construction management education in the rapidly evolving industry landscape.

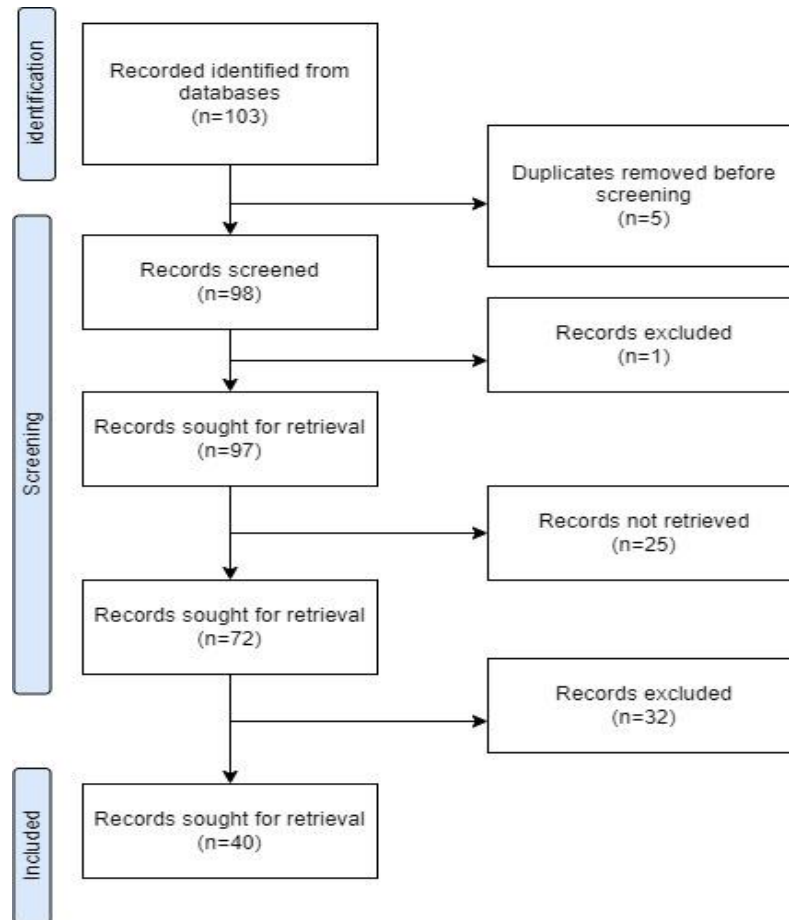


Fig. 1. PRISMA model.

2.1. Search Strategy

A systematic search strategy was developed to identify relevant literature on construction management education and teaching approaches in the Industry 4.0 era. The study employed Boolean operators and multiple electronic databases, including Scopus, Web of Science, Elsevier Engineering Village, and Google Scholar. The search strategy used keywords and controlled vocabulary related to construction management education, Industry 4.0, teaching approaches, competencies, and emerging technologies. By utilising Boolean operators AND and OR, the search strategy ensured a comprehensive coverage of the topic while maintaining relevance and rigour [10]. The combination of keywords and controlled vocabulary terms allowed for a precise and targeted search, enabling the researchers to retrieve relevant articles and scholarly publications in the field of construction management education in the context of Industry 4.0. This

systematic approach to literature search and retrieval is important in ensuring that the scoping review encompasses a wide range of relevant sources and provides a comprehensive analysis of the current state of knowledge. By employing Boolean operators and searching multiple databases, the study aimed to minimise potential biases and maximise the inclusiveness of the review process.

2.2. Inclusion and Exclusion Criteria

Inclusion criteria refer to the essential characteristics of the target population researchers use to address the research question effectively. On the other hand, exclusion criteria are the characteristics of a potential study that meet the inclusion criteria but possess additional attributes that could hinder the study's success or increase the risk of unfavourable outcomes[11]. Clear inclusion and exclusion criteria were established to determine the eligibility of studies for inclusion in the scoping review. The inclusion criteria were:

1. Studies were included if they focused on construction management education, teaching approaches, competencies, and integrating emerging technologies in the Industry 4.0 era.
2. Published between 2018 and 2022
3. Only peer-reviewed articles published in
4. Publications written in English were considered.

Studies that did not meet the inclusion criteria or were unrelated to the research questions were excluded. The study did not include publications made in 2023 because the data collection and analysis process had already been completed by the time 2023 publications became available. Therefore, only publications up until the cut-off date of data collection were included in the study. Excluding publications from 2023 ensures that the study's findings and analysis are based on the available literature up to that point.

2.3. Study Selection Process

The study selection process consisted of title and abstract screening, followed by a full-text review. The titles and abstracts of the identified articles were screened to assess their relevance and potential eligibility. Articles that met the inclusion criteria or showed potential relevance were included for full-text review.

2.4. Data Extraction

A standardised data extraction form was developed to extract relevant information from the included studies in Excel. According to [12], data extraction forms play a vital role in systematic reviews by connecting them to primary research and as the basis for evaluating, analysing, summarising, and interpreting a body of evidence. Therefore, developing, testing, and utilising these forms effectively during the systematic review process is essential. Numerous studies have highlighted the prevalence of data extraction errors in systematic reviews, particularly concerning outcome data. The data extraction form captured key details such as author(s), publication year, study objectives, research methodology, sample size, key findings, and implications related to the current

state of construction management education, teaching approaches, competencies, and the integration of emerging technologies.

The extracted data were analysed to identify common themes, trends, and patterns related to the current state of construction management education, teaching approaches, competencies, and the integration of emerging technologies in the Industry 4.0 era. The findings were organised and synthesised to provide a comprehensive topic overview.

2.5. Reporting

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines reported the scoping review findings. These guidelines provide a standardised framework for transparently reporting the methodology, results, and implications of scoping reviews. The PRISMA statement provides a checklist and a flow diagram that researchers can use to ensure comprehensive and consistent reporting of their review process and findings. The PRISMA guidelines were developed to address the issue of incomplete and inconsistent reporting in systematic reviews, which can affect the reproducibility and reliability of the findings[12–14]. Following the PRISMA guidelines ensured that the results of the scoping review were presented in a clear and structured manner. The reporting followed a systematic approach, enabling readers to easily understand and interpret the findings.

The findings were presented to address each objective of the scoping review. This approach allowed for a comprehensive examination of the research question and facilitated a focused analysis of the key themes, concepts, or gaps identified within the scope of the review. The clear and structured reporting of the scoping review findings was instrumental in conveying the results effectively. It facilitated the dissemination of the research outcomes to the intended audience, such as researchers, practitioners, policy-makers, or other stakeholders. By adhering to the PRISMA guidelines, the scoping review achieved transparency, rigour, and consistency in its reporting, enhancing the credibility and usefulness of the findings.

3. Literature Findings

3.1. Construction Management Education in the Industry 4.0 Era

In the era of Industry 4.0, characterised by the integration of advanced technologies and the digitisation of various sectors, construction management education has undergone significant transformations to meet the industry's evolving requirements[15]. As the construction industry becomes increasingly complex and interconnected, professionals must possess diverse skills and knowledge to thrive in this new era. One of the key requirements of Industry 4.0 is proficiency in emerging technologies. Construction management education has recognised the importance of equipping students with the necessary expertise. It is noted that higher education institutions now offer specialised courses and programs on BIM implementation, digital project management, and construction automation[16]. Therefore students are encouraged to explore the potential of these technologies in optimising project planning, scheduling, cost estimation, and resource allocation.

The Industry 4.0 era emphasises the need for construction managers to possess strong data analysis and interpretation skills[17]. With the abundance of data generated from various sources such as sensors, drones, and mobile applications, construction professionals must be adept at extracting valuable insights and making data-driven decisions[18–20]. Consequently, construction management education now emphasises courses on data analytics, visualisation techniques, and predictive modelling. These skills enable managers to identify patterns, anticipate risks, and optimise construction processes for enhanced efficiency and productivity.

Industry 4.0 demands construction managers who are well-versed in sustainability practices and green construction principles[21]. As environmental concerns become increasingly significant, construction management education incorporates modules on sustainable design, energy-efficient construction techniques, and green building certifications. Students are encouraged to adopt innovative approaches that minimise the environmental impact of construction projects while maximising resource efficiency.

Apart from the technical skills, the Industry 4.0 era highlights the importance of cultivating soft skills in construction management education[22]. Construction managers now consider collaborative teamwork, effective communication, adaptability, and leadership skills essential [23–25]. As projects become more multidisciplinary and involve various stakeholders, the ability to collaborate and communicate across different domains becomes crucial. Institutions now offer experiential learning opportunities, such as team projects and internships, to develop these interpersonal and managerial competencies.

To keep pace with the rapidly changing industry landscape, construction management education also focuses on fostering a culture of lifelong learning[26]. Recognising the dynamic nature of the field, institutions emphasise the importance of staying updated with the latest advancements and industry trends. Students are encouraged to engage in continuous professional development, attend conferences, participate in industry events, and pursue certifications to remain competitive and adaptable in the Industry 4.0 era.

Construction management education has responded proactively to the requirements of the Industry 4.0 era[27,28]. The curriculum now encompasses emerging technologies, data analytics, sustainability practices, and soft skills necessary for success in the evolving construction industry. By preparing students to embrace innovation, leverage technology, and navigate complex challenges, construction management education equips future professionals with the knowledge and skills required to excel in the dynamic world of Industry 4.0.

3.2. Teaching Approaches for Construction Management

In construction management education, teaching approaches and methodologies have evolved in response to the demands of Industry 4.0. Recognising the industry's dynamic nature, educators have embraced approaches that combine theoretical knowledge with practical application, fostering critical thinking, problem-solving abilities, and adaptability.

One widely employed approach is Project-Based Learning (PBL), which allows students to work on projects that simulate real construction scenarios[17,29,30]. By

engaging in hands-on activities, students collaborate, make informed decisions, and navigate the complexities of Industry 4.0. This approach enhances their technical skills and develops important soft skills such as teamwork, communication, and project management.

Experiential learning is another essential component of construction management education. Students are provided with opportunities for field visits, internships, and cooperative education programs, enabling them to gain practical exposure to the construction industry [17,31,32]. This first-hand experience deepens their understanding of real-world challenges and enhances their ability to apply classroom knowledge in practical situations.

Integrating technology throughout the curriculum is paramount to preparing students for Industry 4.0. Tools such as Building Information Modeling (BIM), simulation software, and virtual reality are incorporated into coursework, allowing students to develop skills in project planning, coordination, and communication[33]. By leveraging these technologies, students become adept at using digital tools and processes increasingly prevalent in the construction industry.

An interdisciplinary approach is emphasised in construction management education to recognise the field's multidisciplinary nature[26]. Students are encouraged to collaborate with peers from different disciplines, fostering innovation and holistic problem-solving. Additionally, case studies and industry partnerships bring real-world expertise into the classroom, enabling students to learn from industry professionals and understand the practical application of their knowledge.

Continuous professional development is also emphasised to ensure students remain current with industry trends and advancements[34]. This includes lifelong learning opportunities, workshops, and conferences, and obtaining certifications to stay current in their field.

In essence, by employing these diverse methodologies, construction management education effectively aligns with the demands of Industry 4.0. Graduates have the necessary skills, knowledge, and adaptability to thrive in the digitalised and evolving construction landscape. They are prepared to tackle complex projects, leverage emerging technologies, and contribute to the ongoing transformation of the construction industry.

3.3. The key competencies and skills in the context of Industry 4.0.

In the context of Industry 4.0, construction managers require a range of key competencies and skills to thrive in the rapidly evolving construction industry. Technological proficiency is essential, encompassing expertise in emerging technologies like BIM, cloud computing, IoT, and AI[16,35]. They should understand how these technologies can optimise project planning, scheduling, cost estimation, and resource allocation. For example, BIM enables the creation and management of digital representations of physical and functional characteristics of a construction project, facilitating efficient collaboration and reducing errors.

Large amounts of data are generated regarding Data Analysis and Interpretation, the increasing use of digital tools and technologies in construction projects. Construction managers must have strong data analysis and interpretation skills to extract valuable

insights from this data. By analysing project data, they can identify patterns, trends, and areas for improvement, leading to more informed decision-making.

Digital Literacy: Construction managers must be digitally literate to effectively navigate and leverage project management software, collaborative platforms, and data visualisation tools[36]. These tools facilitate communication, coordination, and documentation throughout the project lifecycle. By leveraging digital platforms, construction managers can improve efficiency, transparency, and collaboration.

Sustainability and Green Practices in the era of Industry 4.0, sustainable construction practices are gaining importance[18,37]. Construction managers should possess knowledge of sustainable design principles, energy-efficient techniques, and green building certifications. By incorporating sustainable practices, they can contribute to environmental conservation, reduce resource consumption, and meet the growing demand for environmentally friendly construction projects.

Adaptability and Continuous Learning: The construction industry is rapidly changing, and construction managers must be adaptable and continuously update their skills. They must embrace lifelong learning, stay updated with industry advancements, and be willing to acquire new skills. This adaptability ensures they can effectively respond to evolving technologies, methodologies, and market demands[38]. **Leadership and Communication Skills** are a necessity. Construction managers are crucial in managing diverse teams and coordinating project activities. [27,39]. They need strong leadership and communication skills to effectively convey project goals, motivate team members, and facilitate collaboration. Clear and effective communication enhances teamwork, minimises conflicts, and ensures smooth project execution.

Risk Management, Strategic Thinking, and Innovation: Construction managers should possess proficiency in risk management to identify and mitigate potential risks throughout the project lifecycle [40,41]. Strategic thinking enables them to develop long-term plans, anticipate challenges, and make informed decisions. Additionally, embracing innovation allows construction managers to explore new technologies, methodologies, and processes that can lead to improved project outcomes and increased competitiveness by investigating the integration of emerging into construction management education.

3.4. Education and industry integration

Several key aspects must be considered in their education and professional development to equip construction managers with the competencies and skills required in the rapidly evolving Industry 4.0. These aspects include curricular adaptation, hands-on training, industry partnerships, research and innovation, professional development and certifications, collaboration, and interdisciplinary approaches, as shown below.

Table 1. Education and industry integration techniques

| Key Aspects | Description | Source |
|--|--|------------|
| Curricular Adaptation | Specialised courses and modules cover BIM implementation, digital project management, and more. | [16,42,43] |
| Hands-on Training | Hands-on experience in dedicated labs or simulation centres using tools such as Building Information Modeling (BIM) software and drones. | [44,45] |
| Industry Partnerships | Real-world exposure to technology, construction, and association practices through collaborations with industry partners | [23,46,47] |
| Research and Innovation | Conducting research projects to investigate emerging technologies' potential uses and latest developments. | [23,48] |
| Professional Development and Certifications | Encouraging students to pursue certifications and training programs to validate their expertise. | [49,50] |
| Collaboration and Interdisciplinary Approaches | Interdisciplinary collaboration with built environment professionals | [1–3] |

4. Discussion

The scoping review findings provide a comprehensive perspective on the relevance of construction management education and teaching approaches in the Industry 4.0 era. The results indicate that higher education institutions have made significant strides in aligning their construction management curricula with the requirements and trends of Industry 4.0. The curriculum's emphasis on integrating emerging technologies, data analytics, sustainability practices, soft skills, and continuous learning reflects a proactive response to the rapidly evolving construction industry landscape.

The review further highlights the evolution of teaching approaches in construction management education, with methodologies such as Project-Based Learning (PBL), experiential learning, and interdisciplinary approaches becoming increasingly prominent. The infusion of digital tools like Building Information Modeling (BIM), simulation software, and virtual reality into the coursework reflects an acknowledgement of the critical role of digital literacy in preparing construction managers for Industry 4.0.

The key competencies and skills identified in the context of Industry 4.0, including technological proficiency, data analysis and interpretation, digital literacy, adaptability, leadership, communication skills, risk management, strategic thinking, and innovation, underline the multifaceted role of construction managers in the new era. While these skills are increasingly being incorporated into the curriculum, it also highlights the need for continuous professional development to keep pace with industry advancements.

Integrating emerging technologies into construction management education, facilitated through curricular adaptation, hands-on training, industry partnerships, research and innovation, professional development and certifications, collaboration, and

interdisciplinary approaches, underscores the importance of a holistic approach to education and industry integration.

However, the findings also underscore the need for further research and improvements in several areas. For instance, while the inclusion of emerging technologies and data analytics in the curriculum is a positive development, ensuring the quality of these courses and their alignment with industry needs is a challenge that needs to be addressed. Additionally, while soft skills are recognised as essential, the effectiveness of current pedagogical approaches in cultivating these skills warrants further investigation.

The review also reveals a need for more industry-academia collaboration in curriculum design and student training to ensure that the skills taught in the classroom are directly applicable in the field. Moreover, the rapid pace of technological advancements in Industry 4.0 necessitates a culture of continuous learning and adaptability among construction managers, yet another area that can be further strengthened in construction management education.

Overall, the findings suggest that while significant progress has been made, there are opportunities for further advancement in aligning construction management education with the requirements and trends of the Industry 4.0 era. Future research could delve deeper into the identified areas of improvement and explore innovative strategies and best practices for enhancing the relevance of construction management education in the Industry 4.0 era.

4.1. Limitations

this scoping review also has limitations that should be considered when interpreting the findings. First, the literature search was confined to articles published between 2018 and 2022 in English only. This might have excluded relevant studies published in other languages or before and after this period. Second, the review focused on peer-reviewed articles, potentially omitting insights from grey literature such as reports, theses, and conference proceedings.

4.2. Future studies

Future studies could expand the scope of the literature search, include grey literature, and conduct meta-analyses to provide quantitative insights. Additionally, primary research exploring the experiences and perspectives of educators, students, and industry professionals could provide valuable insights into the effectiveness of current practices and the challenges faced in aligning construction management education with the demands of the Industry 4.0 era.

4.3. Research Implications

The findings of this scoping review carry significant implications for researchers, academics, and the construction industry.

4.3.1. Researchers

The review identifies several areas that need further exploration, presenting a rich agenda for future research. These include the effectiveness of current pedagogical

strategies in cultivating soft skills, the quality and industry relevance of courses on emerging technologies and data analytics, and the role of industry-academia collaboration in curriculum design and student training. Additionally, researchers could explore how to foster a stronger culture of continuous learning and adaptability among students. Future studies could also consider a broader range of sources, including grey literature and articles published in languages other than English, to gain a more comprehensive understanding of the field.

4.3.2. Academics

The review underscores the need for academics to continuously revise and update their curricula and teaching methodologies to align with the evolving demands of the Industry 4.0 era. The emphasis on integrating emerging technologies, data analytics, sustainability practices, and soft skills in the curriculum calls for innovative teaching strategies and resources. The importance of experiential learning and interdisciplinary collaboration further highlights the need for academics to develop partnerships with industry professionals and other disciplines to provide students with real-world learning experiences.

4.3.3. Construction Industry

The review highlights the changing competencies and skills required of construction managers in the Industry 4.0 era, providing valuable insights regarding talent development and recruitment for the construction industry. The findings also underscore the value of industry-academia collaboration in ensuring that future professionals are well-equipped to meet industry demands. The construction industry can actively shape construction management education by collaborating with academic institutions in curriculum development, providing internships and hands-on learning opportunities, and participating in continuous professional development initiatives.

5. Conclusion

The transition to the Industry 4.0 era has brought significant transformations in the construction industry, necessitating a parallel evolution in construction management education. This scoping review has comprehensively analysed the current state of construction management education and teaching approaches in Industry 4.0. It has shed light on the extensive strides made by higher education institutions to realign their curricula and teaching methodologies to meet the demands of this rapidly evolving industry landscape.

The review indicates that the integration of emerging technologies, data analytics, sustainability practices, and the cultivation of soft skills and continuous learning are now integral components of construction management education. It has highlighted the evolution of teaching approaches and methodologies, emphasising experiential learning, interdisciplinary collaboration, and hands-on training with digital tools. These changes reflect the industry's increasing demand for construction managers who are not only technologically proficient but also equipped with diverse skills, including data analysis, leadership, communication, and risk management.

However, the review also underscores challenges to overcome and areas for improvement. It highlights the need for continuous quality assurance of new courses, more effective pedagogical strategies for cultivating soft skills, increased industry-academia collaboration, and a stronger focus on fostering a culture of continuous learning and adaptability among students.

In conclusion, while construction management education has made significant progress in adapting to the demands of the Industry 4.0 era, the journey is ongoing. The findings of this review underscore the importance of continuous research, innovation, and collaboration among educators, researchers, and industry professionals in enhancing the relevance and effectiveness of construction management education for the future. The insights gained from this review will hopefully contribute to this ongoing endeavour and inform future research, policy decisions, and educational practices in this area.

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