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Gap in BIM Knowledge: Academic Learning and Practical Experience in Civil Engineering

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ABSTRACT

CONTEXT

As the construction sector in Australia expands, proficiency in Building Information Modelling (BIM) has become essential for graduates. However, a noticeable gap exists between the BIM skills taught in Australian universities and the competencies required in the professional arena.

PURPOSE OR GOAL

This study aims to quantitatively assess the gap between BIM skills acquired in academic settings and those required by the construction industry. By pinpointing specific areas of deficiency, the research intends to inform improvements in educational curricula, ultimately boosting the professional preparedness of graduates.

APPROACH OR METHODOLOGY/METHODS

A comprehensive literature review explored the dimensions of BIM instruction in academia and prevailing industry standards. Discrepancies in BIM competencies were qualitatively assessed through keyword analysis. Additionally, the Person-Organization Fit theory (Morley, 2007) provided a conceptual framework that aided in interpreting these discrepancies, enabling a thorough comparison between educational outcomes and industry expectations.

ACTUAL OR ANTICIPATED OUTCOMES

The research revealed significant differences in how BIM is conceptualized and applied in educational settings compared to professional environments. In academic contexts, BIM is frequently presented as a standalone skill, in contrast to the industry's demand for integration within collaborative practices, deviating from the individual-focused approach commonly seen in university curricula. Additionally, there is a lack of emphasis on using BIM for sustainability in universities, contrasting with its critical role in professional practices dedicated to sustainable construction.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

The findings of this study underscore the pressing need for Australian universities to revise their BIM curricula to better align with industry requirements. By incorporating practical applications of BIM that focus on collaboration and sustainability, universities can more effectively prepare graduates to meet the diverse challenges of the construction industry.

KEYWORDS

Building Information Modelling, Curriculum Development, Industry-Academic Gap

Introduction

Civil Engineering graduates are well-equipped to thrive in sectors like construction and engineering consulting, constantly evolving due to technological advancements such as BIM (Turnbull, 2020; Kumar & Parthasarathy, 2016) and originating in the 1960s, early BIM systems, while rudimentary compared to today's technologies, aimed to extract specific information from models (Ingram, 2020). Recognizing BIM's increasing significance, 23 of 43 Australian universities, including the University of Sydney, have integrated BIM training into their programs (Kim et al., 2020; NATSPEC, 2020). At the University of Sydney, BIM education primarily focuses on its application as a practical tool in various courses like CIVL1810/9810/3811/8811/9811 within the civil engineering department, where students use software such as AutoCAD, Revit and Strand7 for engineering design. However, while robust in teaching structural performance analysis, the curriculum does not comprehensively cover BIM as a whole process. This educational shortfall restricts the full exploitation of BIM's capabilities in critical areas like authoring, communication, coordination, and operation, as identified by the Australian BIM Academic Forum (ABAF, 2022; Casasayas et al., 2021; Kim et al., 2020). Person-organization (PO) fit refers to the degree of alignment between the values and goals of an individual and those of an organization, which is achieved when one or both parties satisfy the needs of the other (Chatman & Goncalo, 2001). In this study, PO fit theory is utilised to rationally determine the gap with the framework outlined in Figure 1 below.

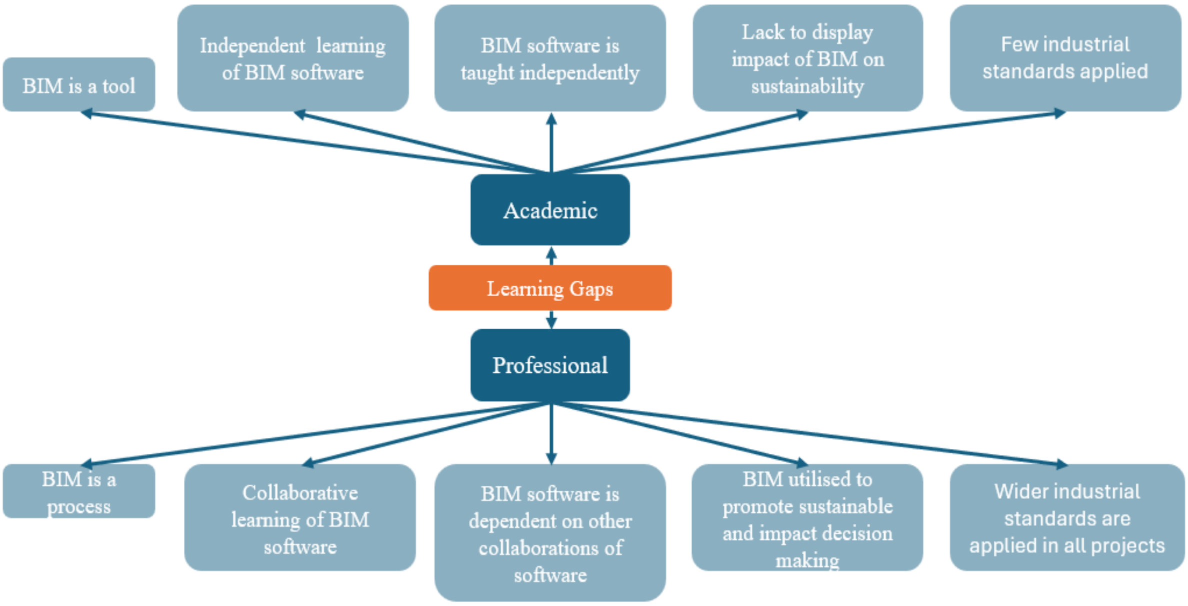

Figure 1: Frame of Academia & Professional Learning Gaps

Objectives

This study seeks to apply the Person-Organization Fit theory to:

1. Identify the essential BIM competencies graduates require in the construction and engineering consultancy sectors.
2. Assess the BIM skills that students acquire during an Australian undergraduate engineering program.
3. Explore the discrepancies between industry expectations and educational outcomes, highlighting areas for curriculum improvement to better prepare graduates for BIM proficiency.

Research Method and Limitations

This study utilizes the Person-Organization Fit theory to examine the discrepancies between academic BIM instruction and industry demands. A thorough literature review, incorporating keyword analysis, synthesizes information on the BIM skills needed in the industry versus those offered by university programs (refer to Figure 2). A limitation of this study is the use of primary data from recent Australian engineering graduates to corroborate the findings in literature. Future research should collect such data to gather insights into their experiences and perspectives on the gap between industry BIM requirements and university BIM education.

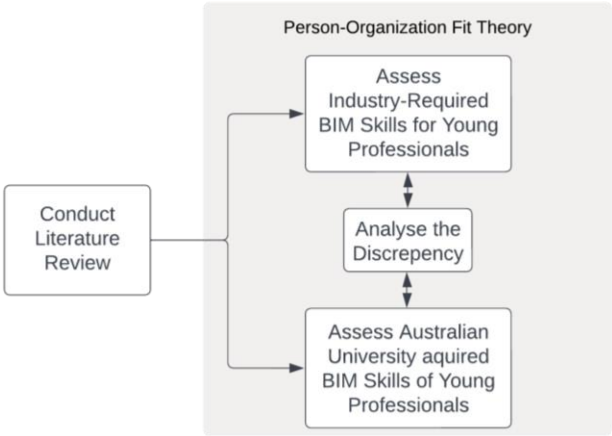

Figure 2: Research Method Flowchart

Results

Keyword Analysis of BIM in an Industry Setting

The holistic integration of BIM across all phases of an industrial project is essential for achieving complete project coherence and efficiency (Kraatz et al., 2014). This comprehensive application of BIM—from initial design to final construction—facilitates meticulous planning and execution at every stage. Universal adoption of BIM can lead to enhanced visualization, more accurate planning, and significant reductions in costs and time delays. As a result, this approach promotes more effective project management and better alignment with industry standards.

One notable advantage of BIM is its role in enhancing cost management. BIM supports the simulation of various risks using an extensive database of risk profiles, which facilitates safer investment decisions (Huang, 2021). Early implementation of BIM across various disciplines aids in identifying and resolving interfacing issues—such as those between civil and mechanical systems—thus reducing risks associated with interface conflicts and overlapping construction activities (Huang, 2021; Nasab et al., 2023). Additionally, BIM is instrumental in improving waste management. It increases construction and demolition waste efficiencies, promoting more sustainable industry practices (Han et al., 2021). A comprehensive keyword analysis (refer to Figure 3) was also performed for BIM in an industry setting, drawing on the literature cited above (Han et al., 2021; Huahui et al., 2019; Huang, 2021; Kraatz et al., 2014; Nasab et al., 2023a; United Nations Development Programme, 2023). Six papers were chosen based on specific criteria for the keyword analysis to ensure a comprehensive understanding of BIM's application in various industrial contexts. Firstly, the selected papers needed to encompass a range of industrial applications of BIM. The selection was limited to studies that provided practical examples to emphasise relevance to real-world industrial settings, deliberately excluding purely theoretical academic research. This strategy helps to mitigate potential limitations in the keyword analysis by ensuring that the inclusion of practical terms offers a broader perspective to readers.

Figure 3: Keyword Analysis of BIM in an Industry Setting

As illustrated by Figure 3, the word cloud shows that terms such as "safety," "construction," "activity," and "risk" are prominent. This indicates that BIM in the industry is oriented more towards processes than the focus in educational settings. The keywords comprehensively represent the construction industry, encompassing its various phases and aspects, including waste management, as highlighted by the term "waste."

Proposed Enhancements to BIM Education

Recent research has contributed to the development of innovative frameworks for BIM education, specifically tailored to architecture and engineering programs. The educational framework proposed by Miller et al. (2013) advocates for a gradual and systematic integration of BIM into existing undergraduate curricula, suggesting further emphasis during postgraduate studies as needed. This framework places a strong emphasis on practical applications, promoting the inclusion of real-life project studies to showcase the extensive capabilities of BIM software outside the conventional classroom environment. To support this educational approach, a keyword analysis was performed using the literature mentioned in the previous section. Python scripts utilizing libraries such as Matplotlib, Beautiful Soup, NLTK, and PyPDF2 were used to extract keywords from all the articles, the results of which are displayed in Figure 4 below (*Beautiful Soup Documentation — Beautiful Soup 4.4.0 Documentation*, n.d.; *NLTK :: Natural Language Toolkit*, n.d.; *PyPDF2 · PyPI*, n.d.; Hunter, 2007).

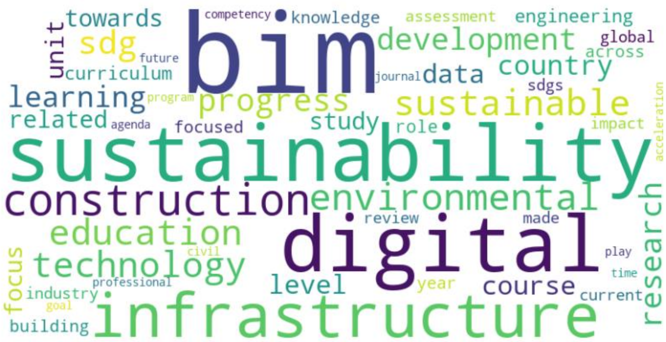

Figure 4: Keyword Analysis of BIM in an Education Setting

The analysis underscores a pronounced focus on the keywords "sustainability," "digital," and "infrastructure" (Casasayas et al., 2021; Badrinath et al., 2016; Doukari et al., 2022; Kim et al., 2020; Miller et al., 2013; Sandanayake et al., 2022). In contrast, there is a distinct underrepresentation of terms like "management" and a lack of characterization of BIM as an "activity." This gap reveals notable deficiencies in the academic BIM curriculum, which are more effectively addressed within the industry.

Discussion

Figure 5, developed from industry-related BIM literature, is presented below.

Over recent decades, BIM education has evolved significantly to align with the needs of the construction industry. Studies show that vital BIM competencies have been effectively incorporated into higher education, improving students' visualization skills and promoting enhanced information exchange across the Architecture, Engineering, Construction, and Operations (AECO) sectors (Badrinath et al., 2016; Doukari et al., 2022).

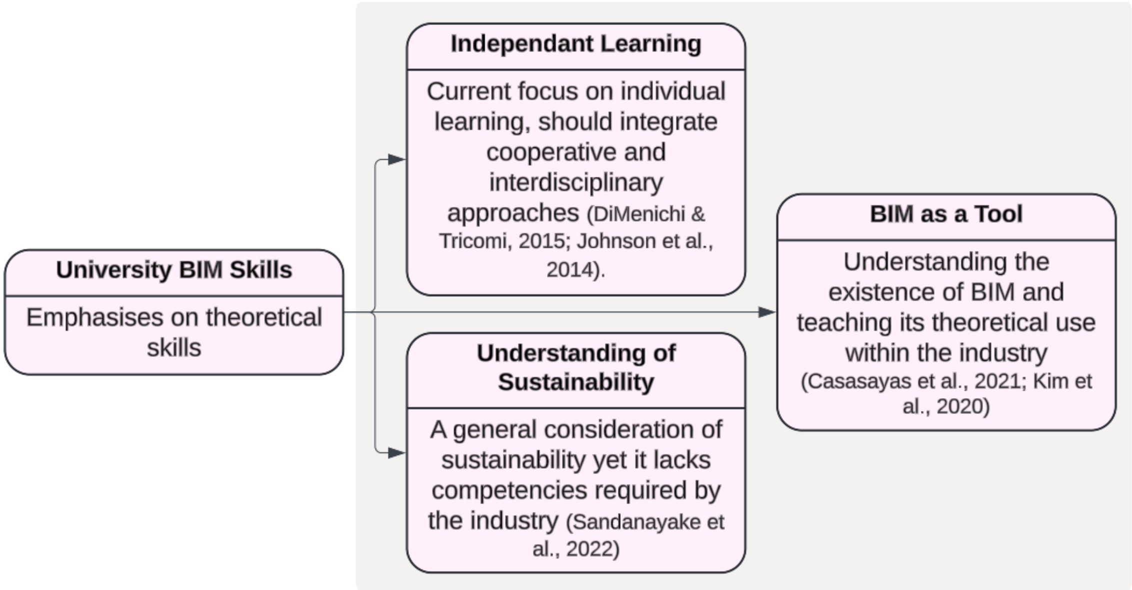

Figure 5: BIM Educational Outlook

BIM as a Tool

Historically, academic curricula have often relegated BIM software to a secondary role, prioritizing theoretical engineering concepts instead. While reinforcing theoretical foundations, this approach tends to downplay the critical role of BIM as an integral process in professional practice. There is an increasing acknowledgment of the need to integrate theoretical knowledge with practical skills to adequately prepare students for the complexities of professional environments (Miller et al., 2013). The Australian BIM Academic Forum recognizes BIM's potential for "Authoring, Communication, Coordination, Simulation and Analysis, and Operation" (ABAF, 2022). Current university courses primarily emphasize skills in "Simulation and analysis," especially in "Structural Performance Analysis." However, the full advantages of BIM are only realized when it is engaged as a process—a competence that graduates are currently unable to acquire from Australian higher education institutions (Casasayas et al., 2021; Kim et al., 2020).

Collaboration in Learning

Current BIM education frequently focuses on individual learning, which might reflect something other than the collaborative essence of professional settings where teamwork is essential. Research indicates that cooperative learning boosts individual comprehension and equips students with the teamwork required in professional environments. Although group activities are becoming more common in BIM education, these initiatives often need a cross-disciplinary perspective and are limited to specific study units (ABAF, 2022). This highlights the necessity for a more integrated and interdisciplinary approach in BIM education to prepare students for the collaborative challenges of the workplace thoroughly.

BIM Design Education for Sustainability

This study primarily identifies the gaps in BIM while acknowledging sustainability as a noteworthy secondary benefit, thus underscoring BIM's expansive potential. A significant advantage of BIM lies in its capability to expedite the development process through an innovative and cohesive platform, boosting productivity and promoting sustainability (Chong et al., 2017). Sustainability is increasingly recognised as a critical component of digital maturity in the industry. Although academic institutions have started to weave sustainability into their curricula, a noticeable gap exists in its practical implementation during the construction phases of projects. This discrepancy underscores the need for a more cohesive educational approach that mirrors the interdisciplinary and collaborative dimensions of professional sustainability practices (United Nations Development Programme, 2023). While sustainability is broadly covered in academic contexts, there is still a lack of specific skills and competencies that graduates are expected to possess when entering the industry (Sandanayake et al., 2022).

Use of BIM and Collaboration

BIM is increasingly recognised as a pivotal tool for enhancing collaboration within the construction industry. BIM enables a more interactive and integrated approach to project management and execution, facilitating seamless communication and coordination among all stakeholders (Huahui et al., 2019). This collaborative environment not only improves project outcomes but also ensures that all team members are aligned with the project goals, enhancing overall productivity and reducing the likelihood of errors.

Industry standards

Engineers Australia has formally accredited the University of Sydney's engineering curriculum, validating its alignment with the requisite competencies for professional practice as delineated by Engineers Australia (The University of Sydney, 2024). Within this framework, digital technology is designated as a tool rather than a process under the "Stage 1 Competency Standard for Professional Engineers," which underscores the necessity for ingenuity, innovation, and proactive strategies. Conversely, sustainability objectives are articulated with specificity and quantifiability, in stark contrast to the more ambiguous targets set for BIM utilization, thereby complicating the tracking and implementation processes relative to other industry benchmarks.

The digital maturity assessment within the industry is conducted through metrics such as the Telecommunications Infrastructure Index and the Data-only Mobile Broadband Basket, which are integral components of the Sustainable Development Goals (SDGs) framework. These indices measure digital integration within the broader context of sustainability objectives, featuring a comprehensive suite of 248 indicators (Methodology SDG Digital Acceleration Agenda Knowledge Partner SDG Digital Acceleration Agenda Supporter, 2023). The divergent interpretations and implementations of digital technology across various institutions result in discrepancies in evaluating the impact of digital technology on educational outcomes versus industry expectations, highlighting the imperative for more standardized methodologies across the educational landscape.

Recommendations to Rectify the Disparity

As per the results and key findings from the literature review, the following recommendations have come to light:

- **Industry-Academia Partnerships:** Through partnerships, guest lectures, and cooperative projects, universities and industry can form an alliance that introduces students to real-world BIM applications and workflows. This also allows further opportunities to analyse the industry-academia discrepancy in BIM skills.
- **New Curriculum:** Academic curricula should be updated on a regular basis to incorporate advanced BIM applications, multidisciplinary projects, and hands-on training modules that adhere to industry standards.
- **Hands-on Learning:** Utilise industry-standard BIM software and tools to provide students real-world exposure. This could involve collaborations with multidisciplinary projects involving students from various degree programs that call for the use of numerous software programs.

- **Professional Development:** Offer opportunities for students to earn certificates or take part in courses on BIM software and how it relates to the engineering and construction fields.

Special attention was devoted to developing a comprehensive figure which can provide full technical recommendations for future teaching and learning in engineering education (see Figure 6).

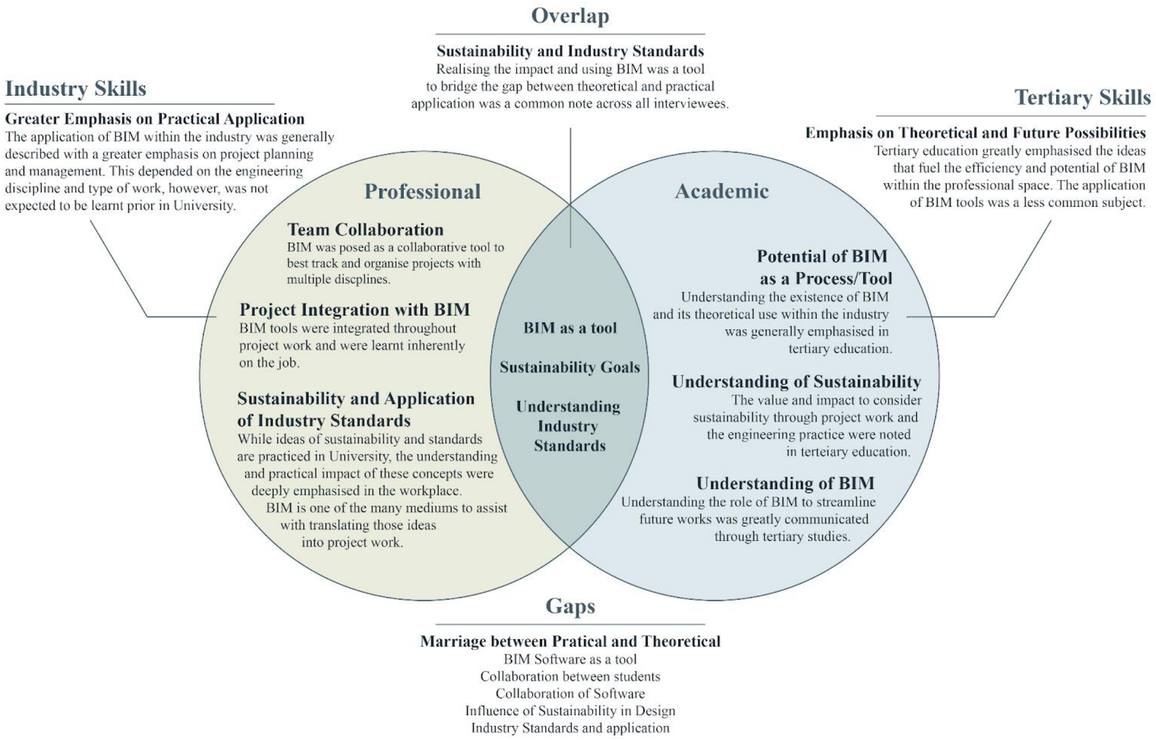

Figure 6: BIM Industry-Academic Outlook

Conclusion

This investigation elucidates a pronounced divergence between the BIM competencies imparted within Australian universities and those requisites mandated by the construction industry. Analysis reveals that academic programs frequently compartmentalize BIM as an autonomous skill, neglecting its essential integration with collaborative processes and sustainability practices, which are indispensable in professional contexts. Utilizing the Person-Organization Fit theory, this study identified these gaps and facilitated the formulation of targeted enhancements for the curricula. To ameliorate this discord, universities must comprehensively revise their BIM curricula to mirror the demands of the industry more faithfully. Such revisions should emphasize incorporating practical applications of BIM that are collaborative, and sustainability focused. This strategic realignment will ensure that graduates are well-prepared to navigate the complexities of the construction industry and transition smoothly from academic environments to professional engagements. For future research, it is recommended that primary data be collected from recent graduates to substantiate the findings presented herein and refine educational strategies further.

Acknowledgement

Artificial Intelligence was utilized to enhance and refine the language quality.

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