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Reflecting on lessons-learned for BIM implementation in design curricula in South Africa

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Abstract

In this paper, the authors reflect on the findings from a building information modelling (BIM) literature review, which comprises contemporary literature from the past five years, considering national and international development of BIM implementations, focusing on the architecture, engineering, and construction (AEC) industries. This study acknowledges BIM as a digitalisation breakthrough that emerged in the third industrial revolution (3IR) and evolved rapidly within the Fourth Industrial Revolution (4IR). BIM technology instils the attribute of being a contributive team member in co-designed projects and facilitates effective project outcomes by reducing time, cost, wastage, environmental impact and energy consumption.

The research aims to identify challenges and opportunities that could inform design education teaching and learning strategies in preparing students for a rapidly changing work environment. Most research shows a need for more training (education) and more profound, deeper working knowledge of BIM within the architecture and interior design industry that impacts the implementation thereof. International findings show a need for experienced BIM professionals and personnel globally in the AEC industries. As a response to these needs, educational institutions have developed BIM courses, and researchers have proposed educational frameworks to assist in meeting the needs of the fast-paced development of BIM.

In this paper, the authors explore the South African (SA) architecture and construction industries' BIM implementation and compare the research findings to international studies. The investigation extracts challenges and recommendations relevant to higher education design curriculum. These findings will be discussed in the paper as lessons-learned. These lessons will be discussed and developed in recommendations that could assist in identifying new pathways in future-forward, industry-relevant architecture and interior design curricula. Recommendations explain that a BIM curriculum is a holistic process that should include role players in curricula development to ensure an alignment with industry expectations. Successful BIM programmes include cross-disciplinary collaborations in which students can work as team members in co-design projects.

Keywords: Building information modelling (BIM), BIM implementation, BIM curriculum.

Introduction

BIM technology has been available for a considerable time, but adopting the BIM methodology in the built environment industries has been slow (Besné et al. 2021, p. 1). Internationally, uptake of the method is observed in the construction industries of the United States of America, United Kingdom, Canada and France due to governmental requirements, initiatives and research driving the change. The introduction of BIM in these industries has led to employment opportunities and the need for experts in this methodology (Besné et al. 2021, p. 2).

Even though BIM technology and the BIM methodology are evident in some of the AEC industries, BIM has yet to be similarly adopted in AEC-related curricula in higher education (HE) as a pedagogical method (Hu 2019, p. 1). Producing graduates with the necessary competencies requires HE to provide students with the essential knowledge and skills to meet and exceed the expectations of the industries they enter. Including the BIM methodology within the curricula can strengthen the link between academic activities and the industry's requirements.

Besné et al. (2021, p. 2) explain that incorporating BIM in AEC curricula should not change this objective but rather "change the teaching/learning methodology". Active engagement with BIM constitutes a new methodology and not only the introduction of new technology. This process emphasises the moves away from traditional drafting-based modelling (Hu 2019, p. 1). The trajectory towards BIM is more than just technological adoption and requires a cultural change in rethinking processes (Salgado 2022, p. 1). BIM has engaged a paradigm shift from conventional drawing practice to digital modelling, which requires the engagement of abstractions and model development processes.

This paper, therefore, aims to understand BIM implementation in SA by asking the following questions: (a) what are the challenges associated with BIM implementation? (b) how are these challenges addressed in the industry? (c) how can these challenges be addressed in higher education to improve students' entry into a fast-paced, technology-driven work environment? These questions will be explored by conducting a literature review to understand BIM development, implementation models, the 'BIM-gap', integration in the architecture and construction industries and HE, the implementation rate, associated challenges and obstacles.

A literature review is considered appropriate since the body of knowledge associated with implementing BIM in SA has increased significantly over the last five years through research output and postgraduate studies in the Engineering and Built Environment faculties at leading research universities such as the University of Johannesburg, University of Stellenbosch, University of Cape Town and the University of Witwatersrand. Through gaining knowledge and understanding of the challenges documented in BIM implementation in SA, the authors will extract findings presented as lessons-learned and guide recommendations for considering BIM implementation into architecture and interior design curricula.

Building information modelling (BIM) methodology and processes

The development of building design software initiated the conceptualisation of computer modelling for buildings (Sacks et al. 2018, p. 367). Eastman is considered one of the pioneers of the BIM concept, which dates back to the 1970s when he proposed the then Building Description System (BDS), which aimed to integrate information technology and building design (Eastman 1976, p. 17). At the time, Eastman described the BDS as having the potential to reduce the cost associated with preparing construction documents and facilitating quantitative analyses. It was also proposed that the design development be better coordinated and allow contractors to receive information for ordering and schedules automatically beyond the design phase. Implementing this approach relied on information management, which required large databases that supported "high rates of information transfer" (Eastman 1976, p. 25).

BIM can also be categorised according to its maturity levels[1] (presented in Figure 1), which refer to the application of information technology and reflects a collaborative process and a sophistication of engagement with various digital tools or BIM platforms (Sacks et al. 2018, pp. 15-16). BIM aims to progress operations amongst the built-environment-associated industries from Level 0, a paper-centric process, toward BIM Level 3, which sees discipline integration and interoperable workflow, streamlining coordinated and collaborative processes. This is achievable by leveraging computing abilities, web communication, and data collection for information management. BIM-enabled design processes allow for informed decision-making based on tangible evidence throughout the lifecycle of a building because BIM comprises intelligent 3D models that use parametric building components that mimic real-life scenarios (Maina 2018, p. 168).

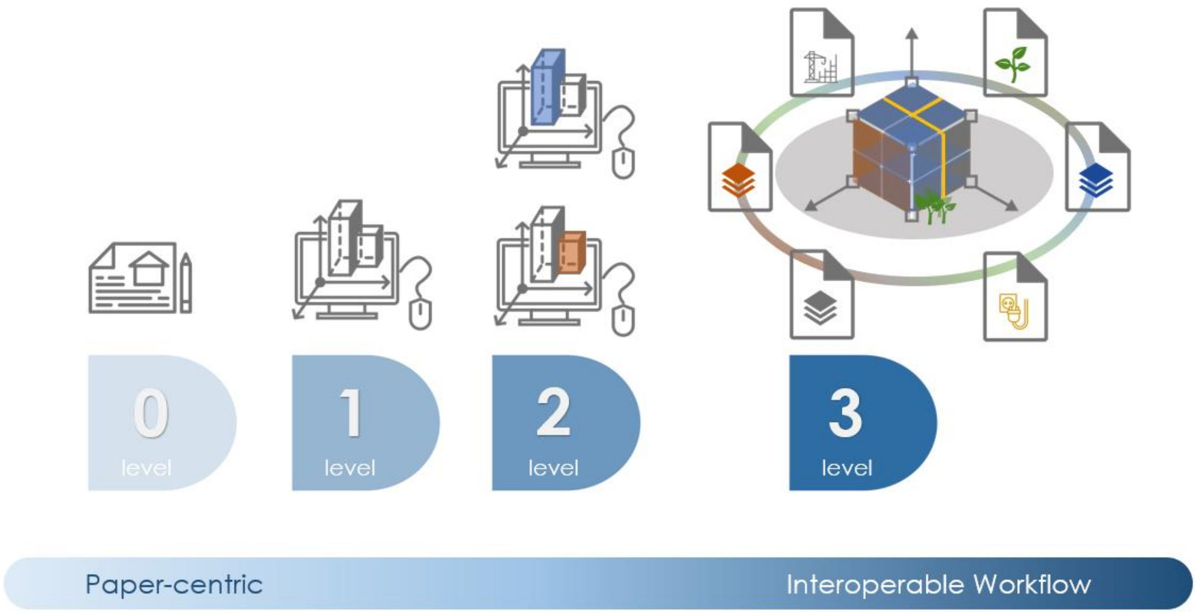

Figure 1: BIM maturity levels, by authors 2023

Many software tools are available to support the BIM concept and activities associated with various disciplines. These tools work alongside the BIM model to support information analyses and provide additional data layers that refer to BIM dimensions. By linking additional data dimensions to building models, the management of building occupancy for maintenance, replacement, and repair can occur beyond construction processes and project delivery. These BIM dimensions can be classified according to 3D to 7D and beyond, i.e., nD, and impact BIM maturity. These BIM dimensions are described by

[1] BIM maturity levels as described by Sacks et al.(2018:15-16):

Level O BIM: Information is available in a 2D format typical of traditional paper drawings.

Level 1 BIM: A mixture of 3D CAD conceptual work and 2D drafting. Digital models are not shared among team members.

Level 2 BIM: Distinguished through collaborative working. All parties work on a 3D model separately, not on a shared model. Information is shared via a common file format, allowing anyone to merge their information with the file they receive.

Level 3 BIM: Collaboration amongst all participating disciplines using a single share project model that is centrally held, for example, in the cloud. The benefit is that it removes the risk of conflicting information.

Maina (2018, p. 169) as the autonomous 3D model (3D), the addition of time for the purpose of project scheduling and managing construction processes (4D), incorporation of cost estimation to allow for budgeting and financial planning (5D), the introduction of sustainability taking into consideration aspects like energy consumption projections (6D), and operational management throughout the life cycle of the building (7D).

As described by Maina, these dimensions are typically focused on the inanimate building. However, researchers like Salehabadi and Ruparathna (2022, p. 11, 13) are critiquing this approach as it does not necessarily track the comprehensive human impact of a building's users throughout its lifecycle. In response, they developed a BIM-based sustainability assessment, which could inform occupants to monitor their impact on a building. This demonstrates that BIM technology in building design is rapidly expanding into sustainable building design and life cycle assessment processes (Salehabadi & Ruparathna 2022, p 13). In addition, we observe that it also demonstrates that BIM supports not only industry professionals but also the public, where users can mindfully engage with the building they inhabit and engage with data concerning sustainability factors, namely, environmental, social, economic, and resiliency aspects.

BIM technologies advanced from merely being a concept to a viable commercial solution around 2000 (Sacks et al. 2018, p. 370). The transition to BIM is "not a natural progression" from computer-aided drafting (CAD). CAD describes the digitising of the conventional drafting process by hand. The trajectory towards BIM is more than just technological adoption and requires a cultural change in rethinking processes (Salgado 2022, p. 1). BIM requires a paradigm shift away from conventional drawing practice to modelling, which requires the engagement of model development processes and abstractions. This can lead to new design processes and building methods. The need for improved collaboration further facilitates this shift across design, construction and facility management processes (Sacks et al. 2018, p. 370).

Traditional and familiar project development processes typically see project members engaging in varying and non-integrated work methodologies due to a lack of a central base of complete and updated information to access, which sees a loss of valuable information through the various stages of the project (Sapaio 2018, p. 18) – a classic case of the 'broken telephone'. The BIM methodology supported by an "information-rich 3D model" is changing the way in which information is managed (Sampaio 2018, p. 20). This integration makes the process more accessible for all parties involved and tracks all aspects throughout the building's life cycle.

BIM-associated technological tools, software and plugins make this approach possible and allow various disciplines to engage in an integrated virtual environment (Sampaio 2018, p. 21). The virtual environment refers to the central base or platform hosted in the cloud. Depending on the BIM platform where the model is hosted, interaction can occur with other BIM professionals not part of your existing or known network of disciplines. This allows discovering other professionals who could join the team to solve and support a project-specific requirement.

BIM and a case for education

Pillay, Gumbo, and Musonda (2019, p. 838) identified that although BIM has been implemented over a short period of time in architectural firms across the globe, in SA, it is limitedly adopted in the curricula. This results in producing graduates entering the industry with poor BIM skill sets and a lack of understanding of BIM (Calitz & Wium 2022, p. 33). A far greater concern is that the slow uptake threatens the SA construction industry's competitiveness and presents opportunities for international companies to perform the work (Calitz & Wium 2022, p. 32). Various barriers contribute to the slow uptake of BIM technology in education and include the complexity of software, available equipment, lecturers' knowledge and training, and time (Pillay, Gumbo & Musonda 2019, p. 838; Calitz & Wium 2022, p. 34). However, education is identified as one of the four main industry role-players who can assist in accelerating BIM implementation in South Africa. The four main stakeholders are listed as "government, the education sector, private organisations, and software developers" (Calitz & Wium 2022, p. 34). The role and responsibility identified for the education sector extend beyond training students and upskilling professionals and should include producing research on BIM to understand the impact and skill sets required in the industry.

Internationally, a change is observed in the education environment, which sees a technological movement aiming to eradicate the barriers to information flow typically created by humanity (Besné et al. 2021, p. 3). Similarly, Hu (2019, p. 2) documents a shift in education which actively engages cross-disciplinary collaboration for BIM implementation. Industries emphasise the importance of BIM concepts, collaborative implementation processes, and skills in BIM tools as critical and complementary and should be actively embraced in curricula (Hu 2019, p. 8). Besné et al. (2021, p. 2) reflect on previous publications, which concur that for someone to engage in collaborative work in a professional setting, that person must have been educated in a collaborative manner, bringing them closer to practice. Adopting BIM and its associated complexities necessitates radical changes in the education environment for effective implementation.

The objective of BIM implementation in the curricula should be to leverage technology for improved processes and not just mastery of the software. This necessitates changing the teaching and learning methodology rather than the curriculum content (Besné et al. 2021, p. 2). BIM should not be misconstrued as merely a 3D modelling software program and reduced to the know-how of operating various software. Some of the software is often also used only for visualisations, and the digital 3D model does not provide any intelligent information at the object level and, therefore, does not support data integration or assist with design analyses (Sacks et al. 2018, p. 20). This approach negates its potential beyond modelling for project management and collaboration processes (Huange 2018, p. 404).

Lessons-learned from research in the industry

BIM implementation is perceived as expensive

BIM implementation has accelerated and shown a spike in implementation in the United States, United Kingdom, Australia, China and Singapore over the last 15 years (Chen, Lu & Wang 2020, p. 401). However, BIM implementation is lower in developing countries (Olugboyega, Windapo, Aigbavboa & Oseghale 2023, p. 3). Calitz and Wium (2022, p. 33) identified the expensive BIM software license as a constraint to BIM implementation in South Africa. From a financial perspective, BIM's biggest challenge is that it is perceived as expensive and increases financial risks when engaging in training, upskilling, and purchasing computer hardware and software.

BIM implementation requires BIM training and staff development

Effective and efficient implementation of BIM in an architectural firm requires staff training and upskilling. Professional BIM training programmes, offered by industry practitioners who are experienced in the software and have hands-on knowledge and experience, can assist in managing the technology change and successful implementation (Chen, Lu & Wang 2020, p. 402).

BIM commitment and support from key role-players and top management

The successful implementation of BIM requires committed key stakeholders who take accountability for facilitating the process. The key role-players in South Africa are the government, the education sector, private organisations, and software developers (Calitz & Wium 2022, p. 34). In this group of role-players, private organisations face the most difficult task. The implementation requires financial risk in introducing new software and work processes, as well as upskilling of professions and staff development, which impact project execution time, effectiveness, and efficiency. Therefore, architectural or engineering firms will prefer candidates with high BIM skill levels who can immediately deliver and contribute to the work process without additional training (Pillay, Gumbo & Musonda 2019, p. 837).

Top management, or the organisation's leadership, determines the project and company commitment towards BIM implementation. Olugboyega, Windapo, Aigbavboaand and Oseghale (2023, p. 4) argue that "the management of construction organisations must commit to the BIM adoption path". These authors further explain that a project-committed management team will take accountability for managing the transition, change, and competence required for BIM implementation. Their research findings also show that construction companies are embedding BIM adoption in their organisations' vision and strategies and setting BIM competency and "new values for their employees" (Olugboyega, Windapo, Aigbavboa & Oseghale 2023, p. 9). If BIM adoption is present in an organisation's vision, it will positively impact the company culture to embrace change and employees' commitment to embrace new learning or be dedicated to the BIM training process.

Resistance to technological change and working in silos

Familiarity with technology and executing tasks, projects and processes in a certain manner is preferred in fast-paced architecture and construction environments. Calitz and Wium (2022, p. 33) identify that resistance to change procedures and collaboration between project stakeholders is a common challenge in the South African construction industry. The established cultural norm is to work in silos and perform tasks within well-known and accepted processes, requiring minimum upskilling or project process negotiation. This challenge is detrimental to the successful implementation of BIM technology. Increased awareness of BIM technology is required to understand the business value, incorporate implementation strategies, and include stakeholder workshops, which could benefit a shared understanding.

Recommendations for the architecture and interior design curricula

In this paper, several challenges and hurdles are identified that impact the revision of architecture and design curricula when implementing BIM technology and processes. The following recommendations were developed from the *lessons-learned* presented in this paper:

The education sector can accelerate the BIM learning curve in SA

A spike in adopting BIM technology is evident globally; however, a far slower pace of BIM implementation is evident in SA. This challenge could be addressed by implementing various curriculum options in higher education and training facilities. Calitz and Wium (2022, p. 34) identify the higher education sector as one of four key role players in developing BIM implementations. The role players cannot operate in isolation, and involving all the role players in the development of curricula could assist in aligning outcomes with industry expectations and increase the successful BIM implementation across all sectors. In addition to meeting industry expectations, education can inject the industry with highly skilled BIM graduates to accelerate the industry's BIM implementation processes and set the pace for renewed, future-focused working methodologies.

Consider various programme options and structures

A BIM programme could range from a series of short learning programmes that address specific theoretical or practical focus areas to a comprehensive inclusion where it is integrated into the major modules of design programmes, such as interior design and architecture. In these modules, vertical articulation between study years could assist in deepening the students' BIM knowledge and mastering the methodology whilst integrating the various building activities into a project solution.

Successful BIM programmes include cross-disciplinary collaborations

The development of BIM curricula requires teaching and learning strategies that are developed across disciplines. BIM training must prepare students for cross-disciplinary industry interaction. In South Africa, interior design programmes are often seen as an outlier to the construction industry, whilst the discipline is well integrated into international BIM projects. Design faculties should include a range of design disciplines that can prepare a student for the complex BIM system that considers expert opinion across various disciplines to contribute to the project design. The student should become familiar with being a team member who co-designs projects with fellow designers. Projects should be designed to simulate a multidisciplinary and interactive experience for students.

BIM is not a CAD software programme

CAD drawings initially replaced the technical drawings produced through hand drawings on drawing boards, with adjustments to 3D CAD programs in the 1980s. As discussed in this paper, BIM requires a paradigm shift from conventional drawing practice to modelling, which requires the engagement of abstractions and model development processes. Embracing this process will enable students to explore new design processes and building methods. BIM is not merely a 3D modelling software program but a platform that allows intelligent information integration, which assists with design analyses and informed decision-making.

Lecturers need to be competent in BIM training

A challenge identified in implementing BIM curricula is that academics have strong theoretical disciplinary knowledge and are not trained in BIM processes and methodologies (Chen, Lu & Wang 2020, p. 402). It is recommended that experienced BIM instructors or facilitators with appropriate training be included in developing a BIM curriculum and offering programmes to develop appropriate BIM-relevant design projects and job-ready graduates.

Implementing BIM requires a project-committed management team

Olugboyega, Windapo, Aigbavboaand and Oseghale (2023, p. 4) explain that a project-committed management team will take accountability for managing the transition, change and competence required for BIM implementation. Successful integration in higher education will require the support of faculty and institutional management to ensure the availability of appropriate funding and resources. A holistic integration into a broader teaching philosophy will assist in a dedicated project implementation. The project team should include programme facilitators well-connected with the industry and within the institution to remove isolated or "silo" thinking and development in the faculties.

Conclusion

In this paper, challenges associated with BIM implementation and how these challenges relate to the South African architecture and construction industry are discussed. The major challenges were identified as the high cost of the software, which impacts slow implementation in SA; skilled and experienced operators are required for the training; financial risk in incorporating new technology and processes; and resistance to change in a fast-paced industry who works efficiently with known technology and who are executing tasks, projects and processes in a familiar manner.

Through the literature review, the authors identified the education sector's role as one of four key stakeholders that can deliver significant contributions to BIM implementation in South Africa. The lessons-learned from the literature identified the following findings: the education sector is an essential role-player in implementing BIM in SA; various curriculum modules could be considered for introduction into HE; BIM allows for intelligent information integration and is not merely a CAD software program; experienced BIM instructors or facilitators are required for successful implementation and due to the high cost and paradigm shift required, BIM implementation requires a project-committed management team.

The research shows that the design education sector can assist in accelerating BIM education and inject the industry with high-level skilled BIM graduates to accelerate the industry's BIM processes and set the pace for renewed, future-focused working methodologies.

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