BIM education at Australian universities: 2020 insights

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Executive summary

This report provides an update of Building Information Modelling (BIM) education and training at Australian universities. Concomitant objectives are exploring the latest BIM advancements while identifying shortcomings to be addressed in improving the quality of training and education offered to students in Australian universities. The report aims to establish a more robust, shared vision between academic, industry and student stakeholders regarding BIM education in Australia.

For policymakers and industry professionals, this report maps the status quo of BIM education in Australian universities, providing the backdrop to plan wider adoption of BIM in Australia. The report outlines best practices for incorporating BIM concepts into curricula offered at Australian universities and will inform related research projects.

A large part of BIM training and education occurs in industry and through various training institutions. The scope of this report, however, is restricted to BIM education and training conducted in Australian universities in the context of fulfilling requirements of a university degree. Any form of BIM training and education that does not meet this definition falls outside the scope of this report.

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Introduction
Following other sectors of the economy such as manufacturing, the construction industry is on the verge of a fourth industrial revolution (Industry 4.0). The ensuing move towards digitalisation will have profound impacts on the industry [1]. Digital technologies and associated innovations will enable construction facilities to be planned effectively, delivered at lower cost, and maintained and operated with higher efficiency [1,2].

BIM is spearheading digitalisation in the construction industry [3,4] and many other technological innovations can be integrated with BIM to advance progress towards the fourth industrial revolution – “Construction 4.0.” [5,6,7,8].

The workforce of BIM is now supported by international standards, protocols and procedures [7], while standards such as ISO 19650 will encourage wider use of BIM in construction [9].

The BIM market is projected to expand at a Compound Annual Growth Rate (CAGR) of 14.5%, from USD 4.5 billion in 2020 to USD 8.8 billion in 2025. While North America currently holds the largest market share of BIM among Architecture, Engineering and Construction (AEC) professionals, the Asia Pacific region is the fastest growing BIM market [9]. See Figure 1.

Increasing BIM market growth has resulted in the development of new work practices, with roles and responsibilities related to BIM gradually becoming established as professional positions within the construction industry [10]. This development presents multiple challenges. One of the most important is to make sure that construction companies are sufficiently staffed with capable BIM employees who can manage the growing number of BIM-enabled projects [11]. The market demand for BIM-savvy professionals is growing exponentially [10].

In the short-term, construction companies have resorted to outsourcing BIM tasks to overseas professionals to fulfil immediate needs regarding BIM-enabled projects [12] but the most viable long-term solution is an ongoing pipeline of BIM-ready graduates supplied by higher education institutions (HEIs) [6].

The National Building Specifications (NBS) claimed that 80% of construction industry professionals in Australia have already adopted BIM – a rate higher than that of the United Kingdom [13]. Notwithstanding this progress, Australian companies still face many barriers in their move towards BIM adoption [14]. Of these, lack of knowledge, education and training in BIM are identified as the major obstacles to the proliferation and widespread use of BIM [13,15,16,17]. The NBS survey revealed that lack of in-house expertise (73%) and lack of training (67%) are the top two barriers to BIM adoption. See Figure 2.

BIM training is therefore among the top three investment priorities identified by the industry [18]. The inclusion of a BIM pedagogy in education is crucial to prepare suitably skilled graduates for the industry [19] and higher education institutions around the world have reflected on this development [18]. In response, BIM education is finding its way into curricula globally, led by progressive higher education institutions and educators [20]. Nationally, many reliable industry sources recommend BIM education as “a foundational activity, a critical need for both industry and academia, and a priority due to the apparent skill shortage in this sector in Australia.” [21 p. 3]

Global BIM market growth at a Compound Annual Growth Rate of 14.5%

Figure 1: Building Information Modelling market overview (adapted from Markets [10])

Figure 2: BIM adoption barriers (adapted from [13])

The Australian higher education sector has made significant advancements in fostering BIM education. However, institutions remain restricted in what they can offer [22] and BIM curricula, where it is offered, varies significantly in quality and content across higher institutions. Moreover, even the best BIM programs fail to deliver BIM-ready graduates because they are limited to covering basic concepts of BIM or developing elementary skills using particular pieces of BIM software [20].

The inconsistency of BIM pedagogical delivery and assessment methods across institutions has the potential to create different student perceptions and behaviours in practice. The community of BIM practitioners, educators and service users in Australia needs to address the disparity in BIM education and converge towards a consistent policy approach [13,15]. There also is a need to identify the barriers impacting integration of BIM into courses and programs as a first step in tackling the challenges and identifying remedial solutions [23,24].

Research shows that charting BIM educators’ practices and perceptions regarding BIM learning, identifying the gaps in institutional education and detecting barriers from the perspective of BIM pedagogy, are essential to enhance college graduates’ BIM readiness in the job market [15,19,23,25,26]. In Australia, this exercise is yet to be undertaken. Consequently, this study is timely and, as the first of its kind in Australia, a key step towards identifying, examining and overcoming the barriers to incorporation of BIM into curricula at Australian universities.

The aims and objectives of this report are:
1. Evaluate current BIM practices and provide an assessment of BIM education across Australian universities
2. Identify the barriers to integrating BIM into curricula
3. Set out remedial recommendations and solutions to overcome these barriers

The Australian construction industry
Construction is the backbone of the Australian economy [27] and a significant driver of economic activity in Australia. It is the third largest employer of Gross Domestic Product (GDP) [28], employing more than 1.15 million people in 2019 [29], with sector employment growth forecast at 10.9%. It is expected that nearly 118,800 additional jobs will be created in the construction industry by May 2023 – a 10% rise in employment [3].

Despite this growth, the construction industry is hindered by some major issues: productivity has been declining steadily over the past 30 years [30] and it is estimated that poor documentation injects project delivery costs by an unnecessary 10 to 15% [31]. Additionally, high construction costs, unsatisfactory project performance, poor safety, low productivity, and poor quality thwart progress [32,33]. As the business environment in the construction industry undergoes change at an unprecedented rate, however, construction projects are growing in terms of scale and complexity. As a result, issues caused by existing impediments are exacerbated by increasing demand for increasingly complex, higher quality products delivered with much tighter scheduling [34].

Other challenges facing the Australian construction industry include recent scandals in building performance quality, exemplified by the cracking in – and evacuation of – the Sydney Opal Tower Apartments [35], and non-compliance with building material safety standards revealed in the widespread use of illegal flammable cladding [36]. A prime example of these challenges surfaced in New South Wales (NSW) where about 85% of high-rise buildings built after 2000 were found to show some signs of structural failure [37]. Australia’s unprecedented population pressure, unmet build stock demand and expanding infrastructure needs signal an immediate need to transform and revitalise the industry [38].
Overcoming these challenges requires changes to the way projects in the construction industry are delivered [39, 40]. Researchers suggest incorporating the following two approaches [41, 42, 43]:

- Restructuring current work processes and;
- Increasing innovation adoption levels.

Improving the industry through technological innovations can resolve many of these issues [2, 27, 32, 43]. BIM has been described as the “trend of the future;” a new disruptive innovation for the industry to address its challenges [44, p.483]. However, BIM has been part of the construction industry for the last 30 years and it would be more accurate to portray BIM as reasonably mature technology.

**BIM in Australia**

According to the ‘National BIM Guide Australia,’ BIM is “a collection of defined model uses, workflows, and modelling methods used to achieve specific, repeatable, and reliable information results from the model.”

BIM emergence milestones

‘Construction 2020 – A Vision for Australia’s Property and Construction Industry’ was released in 2004 and highlighted nine key visions for the industry by 2020 [27]. Out of those, “information and communication technologies for construction” and “virtual prototyping for design, manufacture, and operation” were recognised as the industry strategic visions for development of the digital construction industry in Australia [27]. Construction 2020 was the catalyst for successive attempts towards digitalisation of the construction industry through platforms like BIM. With specific reference to BIM, the first initiatives were the guidelines on digital modelling by CRC for Construction Innovation [45] in 2009 and its 2010 report which recommended BIM as a methodology that can improve productivity in the construction sector. Identified by-products included higher economic wellbeing and competitiveness across the Australian economy [31]. In principle, BIM is seen in Australia as an advanced sociotechnical innovation with considerable popularity in the AEC sector that is capable of delivering these advantages [14, 17, 46].

As a digital process for managing various aspects of project information, BIM has the potential to demystify and coordinate the complexities of large projects, allowing for enhanced design, improved decision making, better identification of clashes, and improved coordination between stakeholders. It is claimed that BIM reduces costs, increases efficiency and optimises project outcomes [47]. According to the Australasian BIM Advisory Board (ABAB), “BIM acts as a single point of truth” [31], however research upholds that BIM must facilitate the automation of trust if it is to act as a single source of truth. It is argued that blockchain technology will enhance trusted collaboration between the construction supply chain’s stakeholders to facilitate this single source of truth. According to Hijazi et al. [8], the assertion is true when BIM is integrated with blockchain and only then can BIM act as a single point of truth. Notably, in the post-construction phase, both policymakers and construction practitioners recognise the benefit of BIM in the operations and maintenance phase of the asset lifecycle [13, 17]. Cost and time can be saved by effectively managing information using BIM [50].

BIM adoption in Australia

Although there is still a long way to go before mandating BIM on a national scale, state and local departments, as well as private sectors, are keen to play a major role in the country’s future infrastructure. Evidence shows that BIM adoption is on the rise in the Australian industry and that it can bring benefits to business [13].

In November 2018, the Queensland Government released its BIM policy: the ‘Digital Enablement for Queensland Infrastructure – Principles’ to meet its goal of implementing BIM on major government infrastructure projects by 2023 [51]. In New South Wales, Transport for NSW (TfNSW) launched the Digital Engineering (DE) Framework Program to create a unified, reliable and reusable approach to DE that would empower more data-driven decisions and enable consistent management of documentation, digital surveys, BIM, and schedules [52]. Victoria has recently released a BIM policy called the ‘Victorian Digital Asset Strategy’ (VDAS) which is highly detailed and goes beyond simple BIM implementation. It is designed to underpin the creation of a “Virtual Victoria” – a digital twin that supports integrated planning and the development of smart cities [53].

In Australia, BIM is typically being used in complex and larger projects. Adoption of BIM in smaller projects and small and medium-sized construction contractor organisations is still limited [54]. With BIM now considered part of the Australian construction industry [55], the industry is required to address barriers to the wider adoption of BIM. One of these is a lack of skilled employees to handle BIM-related jobs [56, 57].

Lack of BIM-ready practitioners in Australia

Delivering projects with BIM-enabled methods and techniques requires project teams with adequate knowledge and skills that are notably different from that of traditional methods [25]. Widespread BIM adoption is therefore stifled by major barriers [14, 17], in particular the lack of skills needed by the construction industry in Australia to progress towards BIM – and the risks and costs associated with access to required expertise [14, 17]. The industry seeks to recruit professionals who can apply BIM knowledge to practical situations on BIM-enabled projects [16, 56, 58].

The Australasian BIM Advisory Board (ABAB) warned that the demand for BIM has remained limited in Australia, mainly due to the “lack of experience in applying BIM.” [55, p.9]

Many other sources similarly indicate that lack of experience in BIM due to limited understanding of industry needs and technical BIM requirements represents a serious barrier to wider adoption of BIM within the Australian construction industry [39, 60].

Higher education institutions play a crucial role in providing expertise to the industry to facilitate wider BIM adoption [61, 62]. These issues, therefore, for the most part have been attributed to the problems of BIM training and education across higher education institutions, as argued in the recent National Specification System of Australia (NATSPEC) 2020 report of BIM education in Australia [57] and many other industry and academic references [56, 60, 61, 63]. An assessment of the nature of higher education in Australia is therefore relevant.

Higher education in Australia

The basic challenge of globalisation is the need to adjust and compete in a rapidly changing environment. Skills acquisition is necessary and people without skills are at an increasing risk of unemployment and unemployment. The onus is on the higher education sector to equip citizens with competencies and skills that meet the requirements of participation in productive roles in an ever-changing society [64]. The economic and social progress of a nation relies on the reach, quality and performance of its higher education system [65]. A major role defined for a nation’s higher education system, especially its public component, is enhancing economic efficiency [66].

**State** | **Universities** | **For-profit** | **Not-for-profit** | **Total**
--- | --- | --- | --- | ---
NSW | 12 | 35 | 25 | 73
VIC | 9 | 15 | 16 | 45
WA | 5 | 6 | 3 | 16
SA | 5 | 6 | 1 | 16
QLD | 8 | 6 | 1 | 16
ACT | 2 | 0 | 0 | 3
TAS | 1 | 0 | 0 | 1
NT | 1 | 0 | 0 | 2
Total | 43 | 68 | 50 | 172

Increase in students (headcount)

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**Significance of Higher Education Institutions (HEIs)**

The operations of higher education institutions (HEIs) generate significant contributions to Australia’s economic output and national income. Australia’s GDP is 8.5% higher because of its graduate workforce (which is 28% of the total workforce). Australia’s higher education system comprises universities and higher education providers [67, 68] which have strong links with the job market. Australian universities currently employ more than 120,000 staff and enrol almost 1.3 million students [67, 68, 69]. For every 1,000 university graduates entering the workforce, 120 new jobs are created for people without a degree. Without universities producing graduates, the growth rate in employment for those without a degree might have been zero over the previous eight years. Universities have arguably been the engine of growth in the employment market [70]. Australian HEIs further provide ample job opportunities for their national and local communities directly through their operations, and indirectly through the students and researchers that they attract to their local regions.

**Figure 3:** Australian higher education sector at a glance (adapted from TEDSA [72])

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**Table 1:** Universities by providers and headcount

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The Australian Higher education structure
The foundation of the Australian higher education system is built on two broad principles: to exist for the betterment of the nation and to open the doors of higher education institutions (HEIs) to everyone [71]. Australia’s higher education sector is comprised of both technical colleges and universities, offering technical, undergraduate and postgraduate qualifications. In Australia, there are 172 registered higher education providers and 43 universities [72]. Of these universities, 40 are Australian, two international and one is a private speciality university. Figure 3 illustrates the distribution of higher education providers across different states. For example, in South Australia there are 16 higher education institutions comprising five universities, one Technical and Further Education (TAFE), six for profit, and four for non-profit institutions. Higher education student headcounts increased by more than 4% in 2017, as shown in Figure 3 which illustrates statistics regarding higher education provider, student and academic staff numbers [72].

Australian Qualification Framework (AQF) levels
The AQF is the national policy for regulated qualifications in Australian education and training and the Tertiary Education Quality and Standards Authority (TEQSA) has regard to the specifications and guidelines throughout the AQF [72]. This integrated policy comprises the learning outcomes for each AQF level and qualification type. Higher education student headcounts increased by more than 4% in 2017, as shown in Figure 3 which illustrates statistics regarding higher education provider, student and academic staff numbers [72].

The Australian Qualification Framework (AQF) spans levels 5 to 10 (see AQF [73] for details), including diploma, advanced diploma, associate degree, Bachelor degree, graduate certificate, graduate diploma, Master’s degree and doctoral degree. Higher education role in providing relevant skills
Due to the rapid evolution of services and technologies, the level of skills required for new jobs and career development is incessantly changing, and consequently prospects for employability are determined by opportunities for skill development offered by HEIs. Evidence shows that about 60% of Australian adults are concerned about the rapid implementation of automation and its impact on the skills needed to secure jobs. Nevertheless, investments in upskilling and reskilling the Australian workforce are considerably slower than other developed countries. The report indicated that only 23% of workers are upskilling through their employer [74], however the Australian Government believes that increasing the nation’s stock of skills will lead to a more efficient and productive economy. Hence, education providers should specify the skills they are teaching, and employers must clearly identify the skills expected of employees [75].

Universities play an important role in meeting future skill demand and producing more intellectual graduates for a high-skilled workforce. Based on current trends, the demand for higher education qualifications will increase by 34% by 2025 – equivalent to 2.1 million more university qualified individuals [69]. In identifying the importance of skills development and student outcomes, the Australian Government’s Productivity Commission has concentrated on the value and impacts of universities’ teaching functions and their role in professional skills and knowledge development [76]. Figure 5 illustrates the Productivity Commission’s focus on skills development and student outcomes.

BIM-related training in HEIs: need for improvement
Both academics and professional institutions have recognised the need for building a sustainable pipeline of BIM-ready graduates. Establishing the education curricula of BIM professional development and business requirements within the higher education sector is therefore a critical milestone towards widespread use of BIM [13, 14, 17, 56]. The National Building Information Modelling Initiative [77] highlighted the role of education to “deliver a broad industry awareness and retraining program through a national BIM education taskforce based on core multidisciplinary BIM curriculum, vocational training and professional development.” In addressing this observation, Perrenet et al. [78] argued for a complete overhaul in construction education that prioritises problem-solving, technology and BIM. In a study by Wu et al. [79] that investigated the importance of 34 industry job requirements, problem-solving, teamwork, communication, and management ranked in the top five — all BIM related. This mismatch between knowledge attained and knowledge required presents as the main cause of graduate unemployment and employer dissatisfaction [80].

Simply put, universities are failing to adequately teach AEC students about BIM [57]. As previously noted, if the construction industry is to evolve from one epitomised by litigation to one of collaboration, both the technology and work culture afforded by BIM must be adopted [58]. However, studies repeatedly show that universities are not satisfactorily preparing students [16, 47, 63, 81, 82]. Arguably, for the construction industry to transform and for BIM to be useful in that transition, the process must begin with education. The Australasian BIM Advisory Board (ABAB) called on “industry, government and academia to further research education and training in BIM” [3]. Evidence shows, nevertheless, that attempts towards widespread inclusion of BIM in HEIs are constantly thwarted by a number of barriers. This in turn has resulted in persistent under-qualification of the contemporary construction-related graduate [56, 63]. A brief discussion on the root causes of these problems in the BIM domain is illustrated in Figure 6.

Inherent problems of HEIs
As shown in Figure 6, the causes of some problems are inherent issues in HEIs in Australia. Education is meant to enrich students’ capacity to lead fulfilling lives and to make meaningful contributions to society, however the current emphasis on economic outcomes often reduces this ideal to one focused exclusively on making students employment ready. Even this simple objective is not guaranteed. As early as 1992, Marshall and Tucker [84] noted that education institutions were failing to sufficiently prepare students to engage with an increasingly complex work environment. Livingstone [85] observed that education institutions characteristically disassociate learning outcomes and work preparation. He described two types of disparity between educational qualification and employability: ‘over-education,’ where the level of education exceeds any job prerequisite, and ‘under-qualification,’ where education fails to prepare an
Cross-disciplinary nature of BIM

BIM is considered a systemic innovation that entails interdependencies between technological, process, and organisational/cultural aspects of the BIM ecosystem. BIM adoption necessitates change, and knowledge and skills to manage this over all three dimensions: BIM-related products, processes, and people (PPP). Understanding the significance of PPP interactions in a BIM ecosystem must be a prerequisite for preparing the construction industry to adopt BIM [93]. An education strategy must focus on training across all interdependent pillars of BIM education, however this adds another level of complexity to designing appropriate BIM training and education.

The evolving nature of BIM roles and skills

As BIM job titles are still evolving and emerging in the construction industry, a common lucid description of competencies pertaining to BIM remains unavailable for BIM roles [10, 79, 94, 95]. According to the Smart ICT report recommendation 06, the Australian Government leans on the UK BIM model; there is no universal agreement on BIM role descriptions and their associated responsibilities [10, 96]. However, this is debatable as there are predefined roles mentioned in the CIC BIM Protocol and PAS 1192 standards [97]. Moreover, significant variance exists in knowledge share, skill set availability and standardisation of jobs between various countries under disparate technological, socioeconomic and cultural contexts [60, 79]. With the above in mind, a comprehensive list of BIM competencies and skills is needed for the Australian construction industry as a basis for developing a BIM competency model for Australian HEIs.

Barriers of HEIs with BIM

A further barrier to BIM education is the absence of knowledgeable educators [58]. Not only are few lecturers able to teach BIM, but university resources and teaching support is lacking and little is being done to upskill teachers or develop curricula [98]. As McDonald [47] reports, AEC programs are already crammed and educators are reluctant to move from their areas of expertise. BIM technology is dynamic, so teaching BIM effectively requires radical alteration in teaching formats. This might include shifting from lectures to workshops, which again necessitates significant transformation of the university teaching environment. The identified barriers further highlight the inefficiencies of universities in catching up with the latest industry developments to embrace BIM [58, 87].

Data collection: methods and techniques

This study performed a website analysis to gather information. Research design and techniques are informed by the methods used by Hasim et al. [99], who conducted a content analysis of 39 Australian university websites to identify sustainability initiatives undertaken by universities. This study therefore relies on the web content of 43 Australian universities as the data source and uses the content analysis method. Website content has been considered as a rich data source and legitimate research tool by many researchers [99].

The list of Australian universities is publicly available online, and the universities’ websites provide information about available BIM-related subjects and courses to provide a higher-level perspective to future students. The design and procedures are illustrated in Figure 7. This review of the content was conducted between March 15 and July 30, 2020. Data from university websites have been collected and analysed in the following three stages (see Figure 7):

Stage 1
Specific keywords such as BIM, Building Information Modelling, 3D model, digital, information management, advanced construction, and smart construction were used to identify BIM-related subjects/courses available in 43 Australian universities.

Stage 2
Different courses, subjects and course outlines were further reviewed to gather information under AQF levels. All qualitative data were gathered in spreadsheets for further analysis.

Stage 3
Certain questions were generated to guide the process of developing the content, as tabulated in Table 1. The data collected in Stage 2 were considered, along with all available relevant documents such as unit/subject guides and course handbooks. Each of the identified subjects was further reviewed based on study area, teaching mode and assessment type. Based on the questions in Table 1, Table 2 outlines the focus of the website content analysis along with considerations for defining and analysing each item. In the description of the findings, various terms have been used to refer to various elements of BIM training in universities. Given that various terms are used by various institutions, Table 3 provides definitions for these terms as considered in this report.

BIM education in Australia: the state of affairs

In recent years, many Australian universities have included BIM education in their curriculum. Figure 8 illustrates the distribution of 24 Australian universities that offer BIM education. The Northern Territory is the only Australian state or territory that does not offer BIM education. Charles Darwin University, its only university, does not offer any construction-related courses, however, the university offers undergraduate and postgraduate engineering degrees, so integrating BIM education could attract a better workforce to the territory.
BIM education across various AQF levels

Content analysis based on Table 2 findings provided interesting insights regarding the number of courses offered across various AQF levels, as well as the number of BIM-related subjects offered by Australian universities (illustrated in Figure 9).

- In Australia, 24 universities offer BIM education in 76 different courses, including eight BIM-focused courses (the remaining courses include different elements of BIM integrated into a broader program).
- A total of 102 BIM-related subjects are offered under the 76 courses.
- There are three AQF Level 6 courses; 26 AQF Level 7 courses; 28 AQF Level 8 courses; and 19 AQF Level 9 courses.

Six BIM-related short courses are also offered by four Australian universities. Figure 9 illustrates the current scenario of BIM education in Australia. In total, 76 courses incorporate BIM-related subjects in their curriculum across various AQF levels and six BIM-related short courses were identified. However, BIM-focused courses remain limited, numbering only eight out of 76 (10 per cent). Of the 76 courses, one in three is at AQF Level 6, two of 26 courses are at AQF Level 7, three out of 28 are at AQF Level 8 and two out of 19 are at AQF Level 9. The remaining 68 courses incorporate BIM-related subjects, with most (24 out of 26) offered at AQF Level 7. In total, 102 subjects under 76 courses integrate BIM into their curriculum while 55 subjects are offered as standalone BIM subjects.

BIM-related subjects’ categories

The literature identified three strategies that have been adopted to incorporate BIM into AEC curricula: (1) developing standalone BIM courses to cover different BIM uses; (2) updating existing courses with a focus on specific BIM uses; and (3) a combination of both strategies [109]. All BIM subjects currently taught in Australian universities can be categorised under strategies 1 or 2 only as a combination of these strategies is not available. It is obvious that a large number of schools are teaching BIM in AEC

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<td>Question 1. How many universities in Australia are providing BIM education?</td>
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<tr>
<td>Question 2. What are the different education levels that incorporated BIM?</td>
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<tr>
<td>Question 3. Are there any generic courses/other courses that teach BIM?</td>
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<td>Question 4. What are the disciplines that included BIM?</td>
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<tr>
<td>Question 5. How many BIM-related subjects were identified up to April–July 2020?</td>
</tr>
<tr>
<td>Question 6. What are the nature/categories of BIM-related subjects?</td>
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<tr>
<td>Question 7. What kinds of BIM knowledge are BIM-related subjects providing?</td>
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<tr>
<td>Question 8. What skills are outlined in the intended learning outcome?</td>
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<tr>
<td>Question 9. What is the scenario of BIM adoption, integration, and collaboration in the BIM-related subject?</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 1: Formulated questions to guide the content build-up for analysis</th>
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<tbody>
<tr>
<td>BIM-related subjects’ categories</td>
</tr>
<tr>
<td>Overview of all universities providing BIM education in Australia</td>
</tr>
<tr>
<td>Universities providing BIM-related content in courses, short courses, subjects, etc. categorised by AQF levels (6 to 9)</td>
</tr>
<tr>
<td>Courses categorised by focus area and distribution of different AQF-level courses in different disciplines</td>
</tr>
<tr>
<td>BIM focused courses concentrate on ‘BIM’ or ‘BIM &amp; IPD’. On the contrary, there are other courses that incorporate BIM-related subjects but focus on design, construction, engineering, management or combined/ multidisciplinary areas e.g. the ‘BIM Specialisation’ course at the University of Melbourne focuses on design, construction and management areas</td>
</tr>
<tr>
<td>Identification of BIM-related subjects offered in different combinations and settings e.g. Deakin University offers ‘SRM751 - Principles of Building Information Modelling’ – a BIM-related subject offered in two different courses: Graduate Diploma of Construction Management and Master of Construction Management Further categorisation of BIM-related subjects based on degree of BIM incorporation Two categories, ‘Standalone BIM subject’ and ‘BIM in various subjects’ have been identified</td>
</tr>
</tbody>
</table>
The term curriculum, broadly defined, includes goals for student learning (skills, knowledge and attitudes); content (the subject matter in which learning experiences are embedded); sequence (the order in which concepts are presented); learners; instructional methods and activities; instructional resources (materials and settings); evaluation (methods used to assess student learning as a result of these experiences); and adjustments to teaching and learning processes, based on experience and evaluation.” [102]

Discipline
“A branch of knowledge, typically one studied in higher education” [101]

Generic course
Relates to education or training delivered at a broader disciplinary level

Higher education
“Higher Education, also known as ‘tertiary education’, consists of awards spanning Australian Qualifications Framework (AQF) levels 5-10, which include: diplomas; advanced diplomas; associate degrees; bachelor degrees (including honours); graduate certificates; graduate diplomas; master’s degrees; doctoral degrees; and higher doctoral degrees.” [103]

Course
“The academic title conferred by universities/colleges as an indication of the completion of a course of study, or as an honorary recognition of achievement. Also known as degree or program.” [101]

Pedagogical approach
“Pedagogy [relates to the] study of teaching methods, including the aims of education and the ways in which such goals may be achieved. The field relies heavily on educational psychology, which encompasses scientific theories of learning, and to some extent on the philosophy of education, which considers the aims and value of education from a philosophical perspective.” [105]

Subject
“The subject of learning is what is learned. Learning is defined as a change in the behaviour potential of a system (a change in competence or ability) in a given situation caused by experience and sustained for some time. The system can be a human being, an organism, or a machine” [106]

Standalone BIM subject
A subject that focuses on learning Building Information Modelling (BIM)

TELQA (The Tertiary Education Quality and Standards Agency)
“TELQA is an independent national quality assurance and regulatory agency for higher education” [107]

Training
“Training is a set of systematic processes designed to meet learning objectives related to trainees’ current or future jobs” [108]
disciplines, however most have only introduced BIM in one discipline, which indicates a lack of collaboration with other subjects. Figure 10 provides an overview of:

- standalone BIM subjects (55 subjects in total, 38 contributing to BIM courses and 17 to other courses) offered across all AQF levels. More than half of the universities (12 out of 24) fall under this category. For example, the University of Melbourne offers standalone subjects in ‘Building Information Modelling and Management’; Deakin University offers ‘Principles of Building Information Modelling’; Bond University offers ‘Building Information Modelling’; Curtin University offers standalone BIM subjects in ‘Building Information Management’; and the University of Western Sydney offers a new unit dedicated to BIM and digital technologies for construction.

- BIM in other subjects (47 subjects incorporating BIM in different subject areas such as cost estimation, scheduling, and business management). For example, Deakin University delivers ‘Planning’ and ‘Scheduling’ subjects with 4D BIM; at the University of Melbourne, BIM is incorporated in a ‘Construction Measurement and Estimating’ subject; RMIT University includes BIM for budgeting and scheduling in its ‘Construction Engineering’ and ‘Construct Planning and Design’ units; and Western Sydney University incorporates BIM in its ‘Building Design Process’ unit at AQF Level 8 and its ‘Smart Construction’ unit at AQF Level 9. At the University of South Australia, BIM for building code checking (building surveying) has been taught since 2018 using Autodesk Navisworks in ‘BUIL 4027 Integrated Project’ (4th year subject), with 4D and 5D BIM being taught in the same course. The university’s ‘Building Design Process’ unit uses BIM tools to develop a 3D model, while its ‘Smart Construction’ unit is more focused on BIM standards, processes and tools for design, construction, and operation.

Researchers [92,109] conclude that introducing BIM in standalone courses is an effective way to quickly cover BIM components because core courses cover a significant amount of other information, leaving insufficient time for educators to explore the full potential of BIM. Previous studies suggest that introducing standalone BIM subjects without any follow-up or collaboration with other disciplines does not support long-term learning, as students do not get the opportunity to implement their skills in different subjects.

To address the limitations of standalone BIM subjects, Cleverenger et. al. (2010) recommended that combining categories 1 and 2 would create a third category which would be more beneficial in terms of preparing students for interdisciplinary collaboration through information exchange and enhancing communication across different AEC fields. In this category, BIM-related subjects would be taught to students from two or more disciplines within the same school/faculty. It is envisaged that this would further help students to face the challenges associated with cross-disciplinary collaboration in the construction industry.

BIM education in different disciplines

BIM subjects are offered in different disciplines including various engineering, construction management and design disciplines (for example, architecture and interior design). In addition to mainstream AEC education, BIM-related subjects are taught within interdisciplinary study programs such as computational design, property management and furniture design. In some universities, the same subjects are taught under various disciplines so it was difficult to categorise them specifically. To simplify the findings, four broad disciplinary categories were identified:

I. Engineering: civil engineering, building surveying, engineering technology, structural engineering, architectural engineering

II. Combined/Multi: civil and infrastructure engineering, architecture and construction management, engineering structure and management, BIM

III. Management: construction management, project management, property management

IV. Design: architecture, architecture and built environment, architecture and construction industry, computational design, architectural studies, landscape architecture/design, interior design, BIM and IPD.

These four categories demonstrated how universities are embracing BIM in courses across different AQF levels and various disciplines. For example, Bond University offers a ‘Master of Building Information Modelling and Integrated Project Delivery’ course under its architecture and built environment discipline. The University of Western Australia’s ‘Master of Building Information Modelling’ course is administered within the design discipline in the Faculty of Arts, Business, Law and Education. Swinburne University is planning to offer an ‘Associated Degree of Applied Technologies- Building Information Modelling’ under the combined/multi discipline. Figure 11 illustrates the distribution (%) of AQF level courses by categorised discipline.

The highest percentage of universities (37.5%) are providing BIM education at AQF Level 8. From Figure 11 it is evident that Australian universities have embraced BIM education, mostly in management and design disciplines across AQF levels 7, 8 and 9. On the contrary, few universities offer BIM-focused courses under the design, combined/multi (AQF levels 6 to 9) and engineering disciplines (AQF levels 7 to 9). Although BIM has been incorporated in various disciplines, universities are dealing with it as a conventional subject. Moreover, different disciplines are treating BIM as a separate subject. The absence of a multidisciplinary approach is
creating confusion among graduates from different study areas. The discrepancies are again consistent with the thoughts of Jin et al. [15] regarding different student perceptions of, and behaviours in, BIM practice.

Curriculum design strategies of BIM-related subjects

BIM subjects are required to support students’ engagement in experiencing and constructing knowledge of BIM implementation workflows [110]. Content analysis of all BIM-related subjects revealed that some focus predominantly on the skills to identify, apply and describe the basic knowledge of BIM principles, maturity levels and drivers, while others prioritise improving technical skills, documentation methods, and BIM execution plans etc. To determine the impact of BIM-related curriculum integration, the authors explored BIM-related subjects and the knowledge base in terms of available content, prerequisites, teaching modes and assessment types. This has delivered a clear picture of current BIM education in Australia and the skillsets acquired by graduates.

BIM technical skills, software and collaboration

BIM-related subjects include a wide range of concepts and tools that can be learnt and applied in project-oriented study programs. As the Australian construction industry has a massive shortage of BIM-skilled technical workers, learning how to use appropriate BIM tools and documentation techniques in study programs would help to create a BIM-ready workforce. BIM-related technical skills, collaboration, and integration of AEC disciplines are complimentary and have a synergistic effect on BIM learning. The literature is inconclusive as to whether BIM software skills are more important than theoretical BIM knowledge in AEC education; industry professionals ranked software skills as the most desired learning outcome [110] up to AQF Level 8, however digital engineering/BIM leadership and management is more applicable at Level 9.

The study has conducted an in-depth search of available web content such as online unit guides and course descriptions of BIM-related subjects to determine the current BIM knowledge base, ranging from BIM documentation, 3D drawing and modelling to environmental simulation. Apart from BIM application, few BIM-related subjects mentioned teaching digital technologies such as platforms driven by BIM-supported virtual reality (VR) to achieve interactive displays during construction education.

Some HEIs offer elementary understanding and knowledge of advanced technologies such as sensing and tracking (3D laser scanning, photogrammetry, etc.), Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR). Some BIM-related subjects claim to provide BIM communication and collaboration skills, but the extent to which they fulfill BIM workplace needs is not clear. Figure 12 provides an overview of different BIM skills (technical and non-technical) taught in various BIM-related subjects. Based on the available content, information was grouped under the following categories to understand the BIM application landscape in universities:

- 3D modelling: modelling, 3D models
- 3D visualisation: visualisation, visualisation technique
- BIM documentation: ISO standards, BIM data, BIM instructions, project briefing documentation, workplace documentation, BIM standards, ISO/PAS/BS, BIM guidelines, legal and contractual issues, knowledge management
- 4D scheduling: scheduling, scheduling simulation, 4D simulation
- 5D costing: costing, quantifying costs from a model
- Environmental simulation: environmental issues analysis, 3D model environmental analysis
- Facility management: asset management, occupancy phase BIM
- BIM coordination: IFC coordination, model collaboration, change management, scanning tools, spatial tools incorporation, data interoperability
- BIM collaboration: collaboration with stakeholder management, construction collaboration
- Digital fabrication
- AR/VR/MR

Out of 102 BIM-related subjects, BIM documentation (82 out of 102) and 3D modelling (79 out of 102) are deemed the most popular methods of BIM application. Some universities use BIM tools like Revit, ARCHICAD for 3D and documentation, scheduling software Microsoft Project, Navisworks, Tekla, Bentley, Intergraph on multiple platforms, Dynamo Solibri (quantity take-offs), Synchro PRO 4D (4D scheduling), Autodesk Recap, Autodesk BIM 360, Unity (advanced visualisation engine), and so on. Design-oriented courses like architecture are more inclined to use BIM for visualisation, whereas management disciplines address more collaborative issues such as teamwork and communication.

Despite the variation of BIM educational activities, there is a need to connect different disciplines through an interdisciplinary approach and collaborative work. For example, subjects like ‘Intellectual property rights (data exchange)’ at Bond University are offered as one- or two-day intensives and claim they will “equip students to better adopt the buildingSMART Australasia BIM framework”.

These insights demonstrate amalgamation of various BIM knowledge, tools and technologies, however there is no cohesion and content discrepancies raise questions as to whether proper BIM skills appropriate to the industry are being developed.

Prerequisites in BIM-related subjects

The importance of prerequisites in BIM learning has been a controversial subject within the field of BIM education [111]. One of the main questions researchers asked is whether students need to learn CAD drawing before learning to apply BIM tools. Some researchers suggest that manual sketching and understanding drawings, working with physical models, and learning CAD are prerequisites for learning BIM. Moreover, BIM users need to have better trade-specific knowledge than CAD technicians as all information required for realisation of buildings must be aggregated in BIM.

Content analysis revealed that only 43% of BIM-related subjects mentioned prerequisites ranging from enrolment requirements to completion of various subjects. For instance, the subject ‘CMG1001 Introduction to Construction Management and the Built Environment’ is the prerequisite for the following courses:

<table>
<thead>
<tr>
<th>AQF Level</th>
<th>Discpline</th>
<th>Design</th>
<th>Engineering</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>AQF Level 16</td>
<td>Combined/Unit</td>
<td>6.17%</td>
<td>6.17%</td>
<td>20.83%</td>
</tr>
<tr>
<td>AQF Level 17</td>
<td>Combined/Unit</td>
<td>6.17%</td>
<td>6.17%</td>
<td>46.67%</td>
</tr>
<tr>
<td>AQF Level 18</td>
<td>Combined/Unit</td>
<td>6.17%</td>
<td>6.17%</td>
<td>33.33%</td>
</tr>
<tr>
<td>AQF Level 19</td>
<td>Combined/Unit</td>
<td>6.17%</td>
<td>6.17%</td>
<td>33.33%</td>
</tr>
</tbody>
</table>

Figure 11: Percentage of universities offering BIM education across different disciplines and AQF levels.
for the BIM-related unit ‘CMG1002 Residential Construction: Methods, Materials, and Management’ at the University of Southern Queensland. However, the information regarding prerequisites is not comprehensive enough to provide an accurate picture of all Australian universities.

Teaching mode
Partial information about teaching modes of BIM subjects is available in web content. For convenience, this was collected and distributed in the seven categories presented in Table 4. Using this information (Table 4), the authors explored the percentage of HEIs offering different teaching modes to deliver BIM-related subjects (Figure 13). More than 90% of universities (19 out of 24) used an on-campus teaching mode, followed by group activities (66.7% - 14 out of 24), practical (52.4% - 11 out of 24) and workshops (47.6% - 10 out of 24). Almost all subjects employed a combination of different teaching modes. For instance, the University of Queensland unit ‘CIVL3510 Project Management with Building Information Modelling’ combined on-campus lectures with practical teaching modes (computer laboratory-hands-on experience of BIM and project management software) and workshops. Few subjects addressed workplace-based learning and problem-based learning methods.

Assessment type
Assessment criteria data for BIM-related subjects is accessible online but detailed information is not available for all subjects. BIM-related subject assessment type information, based on available data, is outlined in Table 5. Utilisation of BIM tools for modelling and documentation is the most common type of assignment in BIM-related subjects. Students also are asked to prepare individual and group presentations. In addition to presentation-, report- and model-based project assessments, assessment by industry professionals and peer assessment methods have been deployed in BIM courses.

As shown in Table 5, most of the assessment types focus on individual learning outcomes of designated subjects and many subject structures are diversified, producing various assessment types. This kind of variation yet again raises the question of disparity in BIM education.

Table 4: Teaching mode categories

<table>
<thead>
<tr>
<th>Teaching mode</th>
<th>Explanation</th>
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</thead>
<tbody>
<tr>
<td>On-campus</td>
<td>Face-to-face lectures, classes, class discussions</td>
</tr>
<tr>
<td>Online</td>
<td>Online learning, webinars, online learning activities</td>
</tr>
<tr>
<td>Workshops</td>
<td>Intensive workshops [2-3 days duration], practice-based workshops, group workshops, intensives</td>
</tr>
<tr>
<td>Group activities</td>
<td>Team-based learning, tutorials, seminars, presentations</td>
</tr>
<tr>
<td>Practical</td>
<td>Computer laboratory, practical learning, problem-based learning, work-based learning, problem-based exercises, problem-based collaborative learning</td>
</tr>
<tr>
<td>Private study</td>
<td>Individual study</td>
</tr>
<tr>
<td>Studio</td>
<td>Desk critiques, studio work</td>
</tr>
</tbody>
</table>

Figure 12: BIM-related subjects - BIM technology and digital engineering incorporation

Figure 13: Percentage of higher education institutions (HEIs) - BIM education deliberating mode
<table>
<thead>
<tr>
<th>Assessment type</th>
<th>Content analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presentation</td>
<td>Oral presentations, class presentations, portfolio showcases, oral pitches, group presentations</td>
</tr>
<tr>
<td>Quiz</td>
<td>Class quizzes, individual quizzes, tests</td>
</tr>
<tr>
<td>Exam assignments</td>
<td>Examinations, theory examinations</td>
</tr>
<tr>
<td></td>
<td>Continuous assessments, learning outcome-based assessments, case-studies, problem-solving reports, self-reflection reports, personal reviews, Microsoft Excel assignments, SPACE GASS assignments, peer review assignments, written assignments, tender assignments, concept designs, energy analysis reports</td>
</tr>
<tr>
<td>BIM report</td>
<td>Reports (application of software tools), group BIM reports, 1000-word reports (BIM role and opportunities), BIM technical reports, BIM implementation plans, BIM business cases</td>
</tr>
<tr>
<td>Group assessments</td>
<td>Individual team contributions, group-based case studies, virtual construction and collaboration, workshop exercises</td>
</tr>
<tr>
<td>Professional activities</td>
<td>Workplace projects, practical projects, industry field studies, month-long onsite activities, facilities management handovers</td>
</tr>
<tr>
<td>Practical/model-based/project assessment</td>
<td>Laboratory activities, design projects, capstone projects, model development, use of BIM applications, extraction of technical documentation from BIM models, practical applications, CAD Revit tests, Revit detail studies, nD BIM modelling, clash detection, construction simulations, quantity extractions, 2D+ 3D graphical representations, 3D BIM model analysis, group projects, model-based construction detailing and documentation, digital models</td>
</tr>
</tbody>
</table>
Integrating innovative learning approaches with frontier construction methods and practices is essential to develop and maintain Australia’s technological prowess. Currently, BIM sits at the interface between priority skills acquisition in the AEC industry and emergent industry 4.0 practices. There is therefore a compelling, though as yet unsatisfied, demand for a BIM-competent workforce and BIM-ready graduates. This report contextualises the status of BIM education in Australia, and its universities’ capacity to deliver BIM programs. An annual update of this report would monitor progress in an effort to develop, implement and deliver improvements in BIM education, in the Australian HE sector. BIM education is offered by higher education providers but also as vocational education through the TAFE sector and through short courses conducted for professionals. Preliminary analysis suggests that relying solely on universities to deliver BIM training is both insufficient and impractical. The totality of the education marketplace must be considered in developing a truly comprehensive BIM education strategy. At the same time, BIM is itself evolving into digital engineering and this will involve integrating BIM with advanced technologies like IoT. These developments, too, should be constantly re-evaluated against the latest developments in the world of practice. Presenting subsequent reports in future years will provide the field with a longitudinal picture of how BIM education has evolved and whether the programs offered continue to meet industry needs.

This is the first inquiry of its kind, and like all first attempts it can be expected that some key considerations may have been overlooked. Interested readers are thus invited to forward comments and suggestions that might improve future updates on this theme. Major limitations are also to be noted. Chief among these is the sole reliance of this report on publicly available data and information drawn from university websites which may not reflect the most recent developments or adequately acknowledge imminent changes. Future iterations will aim to collect data from all active universities and give these institutions the right of reply and the opportunity to expand on publicly disclosed initiatives before subsequent reports are published.

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