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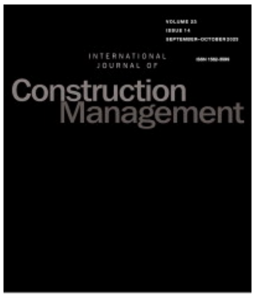

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Case study of the collaborative design of an integrated BIM, IPD and Lean university education program

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ABSTRACT

The increased interest in BIM and the related technologies of Integrated Project Delivery (IPD) and Lean Construction (Lean) highlights the need for enhanced education regarding rapidly evolving technologies within integrated construction-related disciplines. Because of the importance of strong collaboration and open communications to optimal outcomes, the education involved must incorporate soft skills emphasising open mindedness, ability to adapt, teamwork, leadership and communications. In response to the lack of any integrated courses of this nature, this exploratory case study involves the novel development of a university BIM-IPD-Lean Masters-level degree course. This was developed in four phases starting with an initial investigation by thorough contemporaneous review of the relevant education literature and in-depth research to determine the industry's education requirements in full consultation with industry stakeholders, followed by a review of preliminary findings and obtaining approvals, major investigations and program structuring, final approvals and launch. 53 students graduated from the program, with every one becoming employed as a BIM professional within two months of graduation, with some employed during studies, and others immediately after graduation.

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Building information modelling; education; Lean construction; integrated project delivery

Introduction

Building Information Modelling (BIM) involves modelling and improving information flow throughout the lifecycle of construction and infrastructure projects and recognises the need for technology-agnostic methods of exchanging information to achieve this (buildingSMART Australasia n.d.a). The value of BIM lies in its ability to build a digital twin – a detailed, virtual technology-formed image of a completed project – before construction commences (Hardin and McCool 2015), thus facilitating the review and adjustment of designs before construction commences to avoid potentially costly variations, conflict, disputes and disruption later. Its successful application, however, relies very much on developing the required competencies that support the use of BIM to help achieve these benefits (Dakhil et al. 2019). In the words of Young et al. (2009), 'Your career and the prosperity of your company depend on becoming familiar with the tools, processes and value proposition of BIM'. Concomitant with the burgeoning use of BIM are Integrated Projects Delivery (IPD) and Lean Construction (Lean), which are now gradually gaining in popularity.

All have a similar need for acquiring the previously mentioned soft skills because of the importance of strong collaboration and open communications for optimal outcomes. Progress in incorporating such skills into educational programs has been slow, however, with BIM studies having been only gradually integrated into AEC programs in the United States (Bradley et al. 2011) and Australia for instance. The introduction of BIM into universities in the United States and elsewhere met certain challenges, including the level of knowledge required to use BIM software, lack of reference materials, model development not following the construction sequence, lack of intelligent error detection and correction by the BIM software, limited choices of component databases and troublesome BIM-specific software (e.g. Wong et al. 2011). Furthermore, Sacks and Pikas (2013) revealed gaps between what was taught at universities regarding BIM and what industry expected of new graduates.

In response, this exploratory case study describes the novel development of an integrated BIM-IPD-Lean Masters-level program whose objective was to overcome these difficulties in full consultation with industry stakeholders in order to document the process to assist other universities considering designing and delivering programs to serve the specialised needs of specific industries. The study was conducted to ensure that any program developed at the university did not repeat mistakes made by other educational institutions in designing courses and/or programs that addressed highly technical topics in particular industries and to provide some degree of certainty that the program eventually developed met the specific needs of industry, not only so that the industry could meet the requirements of Government addressed earlier, but also so the course schedule suited the weekly schedule of busy industry professionals.

The paper commences with a literature review of the three components in terms of use, difficulties and proposed solutions for developing such a program. This is followed by an account of the phased approach used in the collaborative design of the content and delivery style of the course. The paper concludes with some reflections on the approach used and a brief conclusion, which includes basic data regarding the program's effectiveness as indicated by the number of students employed after graduation.

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Literature review

BIM education

As mentioned, BIM has been only slowly integrated into AEC programs, particularly in the United States (Bradley et al. 2011) and Australia, where only one BIM-specific program existed in 2018, with little interest in BIM-specific programs. Its initial view as an extension of CAD (2D) drawing technology (e.g. Turk and Starčič 2020) meant some early adopting educators focused on architectural students' use of BIM – making sketching competence a prerequisite for taking BIM subjects (Denzer and Hedges 2008). Later developments were problematic because undergraduate degrees provided only the most basic introductory subjects, and relatively few graduates proceeded to post-graduate construction studies. BIM education has also created a major challenge in curriculum development, typically relating to BIM subjects that should be included in existing programs or a full BIM program that should be launched (e.g. Chen et al. 2020) – a standalone BIM subject within a broader program being potentially disruptive because students experience a learning environment vastly different from open, broad courses (Wu and Issa 2014). Similarly, subtle complexities are involved in launching a BIM program, as BIM involves disruptive technologies (Eastman et al. 2011) already addressed in existing subjects, and disruption would have a major influence on appointing lecturers. Moreover, a continuing challenge for universities has been a lack of interest in teaching some required material or the inability of already highly committed internal resources to teach it (Becerik-Gerber et al. 2011; Huang 2018).

Several proposals have been made to ameliorate these difficulties, including the need for BIM education to extend beyond modelling, scheduling and estimating skills to cover all aspects of design, construction and facilities management through modern approaches of 3D-design, 4D-scheduling, 5D-cost, 6D-energy efficiency and 7D-facilities management (Abdirad and Dossick 2016), and the need for courses to emphasise that BIM is intended for modelling functions and behaviours of all building systems and components (e.g. Hardin and McCool 2015). Moreover, the complex and challenging nature of developing pedagogical strategies for BIM education means that educators must consider broader curriculum design issues and trade-offs between educational outcome advantages and disadvantages (Abdirad and Dossick 2016).

Regarding the incorporation of BIM into existing university courses, Sacks and Barak (2010) point to three available approaches: 1) integrate BIM into existing courses, 2) create new subjects or courses or 3) combine the previous two approaches. Of relevance to this is the recommendation that new courses should embrace the cross-discipline nature of BIM implementation (e.g. Denzer and Hedges 2008), with the best BIM outcomes said to be achieved in collaborative, open-communication environments, with teamwork and communication skills being part of BIM program content (Al Hattab and Hamzeh 2015; Abdirad and Dossick 2016). The need for a collaborative approach has also been emphasised in curriculum development, with universities recommending working with industry professionals to develop BIM courses (Wong et al. 2011). In this respect, an integrated framework informed by a collaborative effort between industry professionals, educators and researchers is an essential prerequisite for delivering effective BIM education (AIA and Consult Australia 2012). Several BIM frameworks have been produced for professionals, including the bSA framework, and for educators, including the Collaborative BIM Education Framework (AIA and Consult Australia 2012), which promote collaborative BIM education (based on AQF), and collaboration between industry and universities in developing new BIM programs. The AIA and Consult Australia have supported *OpenBIM* and IFC-friendly technology and encouraged educators to work with industry to ensure a BIM skill shortage is effectively managed and rectified (AIA and Consult Australia 2012). The buildingSMART institution posits that IFC facilitates seamless exchange and transference of information between a broad range of BIM software and is central to the *OpenBIM* approach to modern construction design and delivery (buildingSMART n.d.b). The value of International Foundation Classes (IFC) file system-compatible software and technology in BIM courses must also be recognised (Gier et al. 2006).

Integrated project delivery (IPD) and Lean construction (Lean)

IPD is a contractual delivery system in which '… proper implementation facilitates advanced sharing of information and early identification of shareholders through proper timing as vital keys to realise objectives of the construction projects, reduce risks and increase the chance of project success' (Kahvandi et al. 2017, p.99). Similar to BIM, it ideally involves a collaborative alliance of process and culture in projects adopting IPD and supporting technologies by different people from different disciplines within different organisations with different objectives, needs and cultures (Baiden et al. 2006, p.14). This collaborative nature of the IPD approach has resulted in many projects meeting or bettering budget and schedule targets (e.g. Hanks 2015) because all key factors are considered in an integrated manner from the outset by a team working in an environment of respect and trust, sharing risk and reward in a manner satisfactory to all stakeholders, and working transparently with open communication towards achieving objectives clearly defined from project inception (AIA 2007).

In 2016, Kahvandi et al. (2016) reported that there had yet to be a comprehensive study regarding trends in IPD, concluding that this contributed to a lack of familiarity among construction project stakeholders. This was possibly explained by IPD being a delivery approach often seen as appropriate to larger projects, where increased complexity was associated with increased risk and uncertainty – factors that positioned IPD as attractive (Lee et al. 2014).

However, some traditional contract consultants regarded IPD as a sophisticated form of cost-plus contracting with substantial risk to clients, and a change from that position required attitudinal, contractual, technological and cultural adjustment. There was scant evidence to suggest this widely prevailed among industry professionals (Lee et al. 2014; Kahvandi et al. 2017). This is important given the comprehensive nature of IPD, which requires the involvement of all project stakeholders from as early as possible (e.g. Thomsen et al. 2009), as does BIM (AIA 2007) and Lean (Matthew and Howell 2005; Ballard 2008; Alves et al. 2012). According to Lee et al. (2014), from an educational viewpoint, IPD education is necessary to prepare today's students for making a competent contribution to future IPD projects.

Lean construction (Lean) is defined as 'a way to design production systems to minimise waste of materials, time, and effort in order to generate the maximum possible amount of value' (Koskela et al. 2002). This depends to a large extent on information exchange, for, as Al Hattab and Hamzeh (2013) observe, the major source of information waste, as much a concern for projects in the design phase as materials waste during construction, is sub-optimal sharing of project information. The main challenge to its survival and growth has been the need for more practitioners, researchers and educators (Alves et al. 2012). Some negativity also derives from contractors perceiving the cost of its integration into their business will erode already thin profit margins (Patching 2018). However, a recent emphasis on practitioners moving beyond the Lean core value of waste reduction/elimination towards avoiding waste of human energy by *eliminating adversarial relationships and encouraging structural change in project governance* is expected to facilitate broader acceptance of Lean (Tezel 2016). Moreover, the increasing emphasis on environmental issues as the 2030 date nears for the achievement of the United Nations' 17 goals and 169 objectives for sustainability gives rise to not only the importance of applying Lean principles, so well-proven in manufacturing, within the construction industry, but also to doing so as part of a practical and effective ESG (Environment, Social, Governance) strategy for project owners/developers, financiers and builders.

Along with a lack of understanding, industry culture, commercial pressures and senior management commitment, lack of education has been a major barrier to Lean implementation in the U.K. (Bashir et al. 2010). Sarham and Fox (2013) supported an opinion that also found education issues to be one of the top ten barriers to Lean advancement in the U.K. According to Ogunbiyi et al. (2013), the take up of Lean is dependent on its value being recognised as a contributor to organisational strategy achievement, which necessarily requires knowledge enhancement through education. The uptake of Lean in Australia has been slow, not least because it has not been a key focus of designers or owners, and contractors tend to believe it is too costly for them to take prime responsibility for Lean on all projects – this despite clear advantages to contractors having been reported from those who have applied what principles they could on their sites, notwithstanding designs that might achieve optimally effective Lean impossible. Increasing emphasis on ESG requirements by bankers, trust managers and other major organisations that support construction is expected to lead to rapid change in this area quickly, and so it was regarded as essential that Lean principles education be included in the subject program.

There was a concurrence between the literature and industry professionals that the optimum impact from BIM, IPD and Lead will be achieved when all are applied and utilised in an integrated and collaborative manner.

BIM, IPD and Lean

There are many connections between BIM, IPD and Lean. For instance, it is considered that any increase in the use of Lean and IPD will remain dependent on future professionals currently studying construction programs (AIA 2010; Alves et al. 2012; Ashcraft 2014), and upon universities bridging the gap between industry and academia through research and publications. Several studies in the United States between 2001 and 2016 revealed IPD to be a key tool in successful implementation and was especially effective when combined with Lean principles (Ashcraft 2014). Hardin and McCool (2015) emphasise that BIM facilitates IPD. Young et al. (2009) posit that the construction industry would see the integration of BIM, Lean and green, with Bradley et al. (2011) agreeing that BIM, Lean and sustainable design and construction would shape construction industry change.

Al Hattab and Hamzeh (2013, 2017) emphasised the combination of all three, in that BIM, IPD and Lean embraced principles from the other and are synergistic technologies that rely on each other to produce the best outcomes – especially for BIM and Lean use. There is an increase in the use of BIM, Lean and IPD on complex projects (Alves et al. 2012), especially in western states of the U.S., which was largely attributed to the increasing use of the AIA-IPD form of contract (AIA 2010). In Australia, BIM popularity has been boosted by bSA and by the public sector requiring BIM use on major projects; however, IPD and Lean are not experiencing equally rapid growth. The perception of IPD as a complex projects application is a global hindrance, as is a reticence by the public sector to move away from the lump sum contracting approaches often regarded as delivering the best value for taxpayers (e.g. Lee et al. 2014; Al Subaih 2015).

Taken together, this has created a need for construction educators to focus not only on reducing/eliminating waste, but also on the collaborative creation of value (Alves et al. 2012) – solid support for a BIM-IPD education combination (Matthews and Howell 2005; Thomsen et al. 2009; Lee et al. 2014).

Moreover, as the public sector increasingly demands competence among consultants and contractors in BIM, IPD and Lean skills, there will be pressure on universities to teach those skills (Hardin and McCool 2015); BIM technology is developing quickly, making it prudent to involve industry professionals in frequent reviews of BIM-Lean-IPD curricula, or to engage them in subject delivery (Matthews and Howell 2005; Lee et al. 2014). In the United States, 26 percent of universities offering construction management courses include Lean content, 88 percent believe IPD should be taught with Lean and 69 percent state that IPD should be taught with BIM (Lee et al. 2014). Interestingly, 100 percent of students in one U.S. study expressed interest in learning about Lean, while only 14 percent regarded BIM as beneficial to understanding construction methods – informing the importance of educating students of the benefits of all of BIM, IPD and Lean. A recurring theme is a need for enabling skills training in BIM-, IPD- and Lean-related courses with an emphasis on open mindedness, ability to adapt, teamwork, leadership and communications (e.g. Sacks and Pikas 2013), because of the importance of strong collaboration and open communications to optimal outcomes.

Important findings from the literature influenced the choice of method and approach. The most salient arose from comparing and contrasting the comments of Sacks and Barak (2010) regarding integrating new material into existing areas of study with those of Sacks and Pikas (2013) regarding determining the gaps in what was currently being taught and what was required. The determination of the method for the research into program requirements was strongly influenced by insights gained from this comparison, especially regarding the paramount importance of the demands of industry members (what education was available to them) compared with what they required in a quickly changing business environment with active Government requirements that, at the time, could not be met.

Methodology

The case study method was participatory, involving information gathering to make decisions regarding Bond University's potential BIM-related programs (Brookshier 2018). This involved:

- Data collection via a focus group meeting with the key industry body for BIM in Australia

- Organising separate meetings to collect data from professionals from industry and Government (n = 46) as recommended by the President of the BIM key industry body
- Collecting data regarding contract delivery methods, with an emphasis on IPD, from participants involved in the previous steps who had relevant experience in contracts
- Collecting data via in-depth interviews with specialist consultants or contractors in Lean construction (n = 6)
- Collecting data relating to attitudes to the inclusion of each BIM, IPD and Lean via less formal discussion as described earlier with industry members. Details of actual numbers relating to each topic were not recorded, given the circumstances of several of these discussions, but the total number was at least fifty
- Revisiting notes taken from interviews and discussions with representatives of professional institutions and comparing data from more formal collection processes with that from more informal approaches as described previously
- Combining the two separate schedules used to firstly complete the initial investigation and make the decision to proceed into a more detailed investigation, and secondly to complete the detailed investigation project
- Constructing the case study by providing details regarding activities or groups of activities within that combined schedule
- Describing the outcome of the investigation and presenting results and recommendations

Figure 1 shows the schedule of process steps used for completing this case study. The study is described in the next section concerning these steps.

The investigation began with a focus group discussion with industry representatives in mid-2018. Focus group engagement was used as the literature well supports it (e.g. Kymmell 2008) and avoids creating cognitive dissonance between academic learning and industrial work (Turk and Starčič 2020). Three senior BIM experts and five academics, including an Executive Dean, were involved. The president of buildingSMART Australasia (bSA) participated. This senior management sponsorship of, and engagement in, the initiative was considered essential to success (Patching and Waitley 1996). The high regard in which industry peers held the panel members added important gravitas (Kezar and Eckel 2002).

One important aspect of the method needed to be planned but proved particularly useful and provided valuable data. When the subject study was planned and conducted, there was no intention to write a journal article. The researchers' sole objective was to design and deliver a world-leading university program. However, as industry members learned about the research, numerous unsolicited approaches were made to one researcher at conferences, monthly industry meetings and *via* telephone. Typical examples include impromptu meetings of up to an hour's duration held with senior BIM and Lean specialists (separate meetings) from Australia and overseas at a conference. Initially, data so collected were kept separate from that more traditionally collected, and the datasets were compared. The level of consistency was found to be extremely high, after which data were merged and regarded as a single dataset.

A simple analysis of industry concerns from the data identified key themes addressed in the eventual design and construction of the subject program. Among those were actual program content, concerns regarding weekdays required for study, desire for high levels of practical content and hands-on learning and within-subject assessment (i.e. no after-class examinations).

In qualitative method terms, the strong consistency expressed by participants regarding requirements effectively constituted reaching saturation early in the data collection process, and continuing discussion with industry members out of respect for their volunteered contributions, while not necessarily given saturation had been achieved, nonetheless provided a useful confirmation.

The Bond University Human Research Ethics Committee, reference number AP200626, gave ethics approval for the study.

Case study

Phase 1 – initial investigation

The initial meeting provided valuable insights into the BIM industry's educational requirements. This pointed to an increasing need for education covering the full extent of BIM, integrating BIM information technology (IT), and the need to extend beyond (commonly taught) 3D modelling and 5D cost management to include 4D scheduling, 6D energy efficiency and 7D facilities management. The emphasis on these needs aligned with Azhar (2011) and Sacks and Pikas (2013), and indicated the need for 12, 10 and 17 items under the Process, Technology and Applications headings, respectively. These items are presented in Table 1 with a notation regarding how they were addressed in this case study. The initial industry meeting also confirmed, because of the collaborative nature of BIM team environments, that education courses should cover intellectual property rights – a matter often overlooked, even in current contracts. The engagement also revealed the prominent issue of the academics' support for including IPD content with any new BIM program and industry promoting Lean.

The important results from this initial focus group include the following:

- Several Australian universities already offer BIM-related subjects, and one offers a BIM Master's degree. That existing course focuses on concepts of collaborative behaviour vital to the design process
- There is a need for industry-informed BIM programs designed to meet the needs of full-time professionals
- There is a demand for post-graduate courses in BIM
- The use of BIM in an IPD environment raises the potential for complex disputes, and therefore including a subject addressing contracts and intellectual property rights was endorsed
- As implied by Kymmell (2008), there is a need to focus on BIM management/leadership/coordination skills rather than technical BIM-IT skills
- Many construction professionals saw BIM as an extension of CAD (2D) drawing technology, a limited view also seen in the literature. Any new program should dispel that inaccuracy and educate people about involvement across all BIM competencies
- The most salient information from the initial session was the importance of *OpenBIM* and the use of the IFC file format in all educational content of new university programs

Broader consultations proceeded with adjunct staff experienced in IPD or Lean before the broader industry consultation progressed. Several opined that IPD was unimportant and was little more than a United States version of Australia's Alliance Contracting. The Lean expert (adjunct) lobbied for including Lean in any BIM or IPD program, a position supported by the literature, as demonstrated in addressing item 3(a).

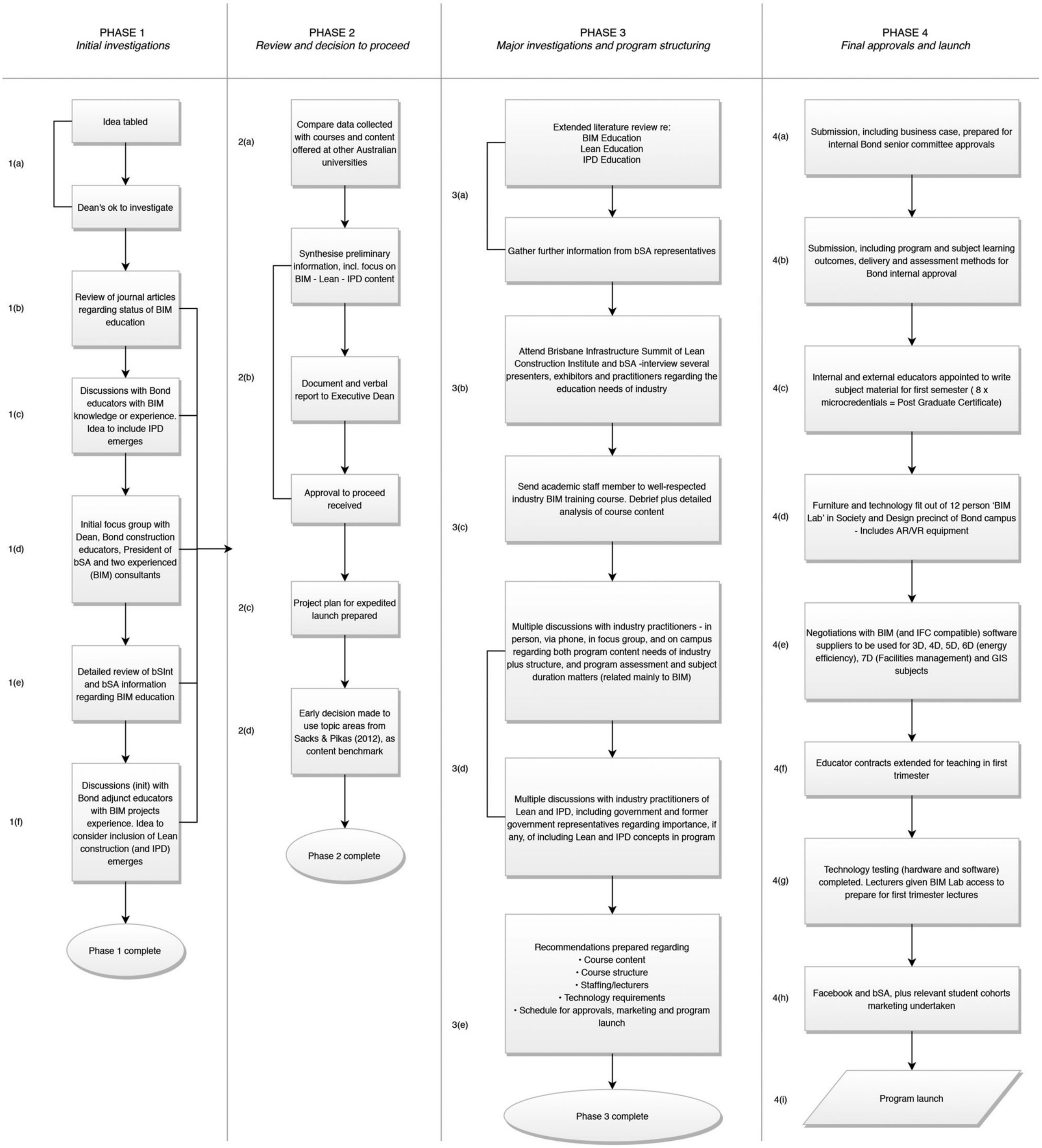

Figure 1. Combined process steps used.

Phase 2 – review of preliminary findings and gaining approval to proceed

In step 2(a), the conclusions from data from industry professionals were compared with subject offerings at Australian universities. This informed a preference for launching a post-graduate program to appeal to industry professionals and university alumni (with cognate undergraduate degrees) who wanted to upskill for career advancement.

In addition, bSA's suggestions remained highly relevant concerning:

- commencing any program with a subject overviewing all aspects of BIM
- emphasising the program would follow the bSInt and bSA framework
- describing the importance of *OpenBIM* and explaining how it would be taught both in theory and by substantial program practical components
- including a subject addressing intellectual property rights

The three items labelled 2(b) collectively represented understanding the data in the context of offerings from other universities and perceived current and future needs of industry. University approval was received to proceed with broader and

Table 1. Responses to key questions asked of industry professionals ($N = 46$).

Question	N/A	Yes	No	No strong opinion	Comments (by author or respondent)
Is there a need for more BIM university programs in Australia?	0	41	0	5	'With upcoming government-funded BIM work, there is a pressing need for courses that cover all aspects of BIM in the shortest duration possible'. (Future Infrastructure Summit delegate)
Would the program be more appealing if Lean was included?	14	18	4	10	The 14 N/A respondents had little knowledge of Lean or considered it a question for contractors.
Would the program be more appealing if IPD was included?	0	28	14	4	The 'no' and 'no strong opinion' responses are explained in the text of this paper.
Is IPD more important to include than Lean?	0	15	24	7	Reasons for the 'no' response are given in the text of this paper.
Should BIM, IPD and Lean be taught in one program?	0	42	1	3	This appeared to be a strange response outcome, given the nature of responses to the previous question.
Is a program involving three days per week for eight weeks acceptable to industry?	0	21	12	13	'The BIM area is very busy, so the courses that will work for industry will take the shortest duration possible, cover all areas of BIM and lead to some formal qualification. Include Lean and IPD at an overview level, but the need now is for practical BIM courses that can produce competent BIM project managers quickly'. (Senior construction consultant from Brisbane)
Will industry be interested in micro-credentials as explained?	0	38	0	8	The response was instrumental in deciding micro-credentials would be part of the program structure.

deeper investigations regarding the viability of a post-graduate certificate program and, if warranted, a full Master's degree.

Item 2(c) described the preparation of a project plan for Phases 3 and 4 (Figure 1). Step 2(d) evolved during the preparation of that plan and referred to ensuring all recommendations regarding BIM course content made by Sacks and Pikas (2013) were considered in finalising any program.

Phase 3 – major investigations and program structuring

Item 3(a). This overlapped with items 3(b), 3(c) and 3(d), and began with a discussion with the bSA president regarding Lean and IPD education based upon findings from the literature.

Item 3(b). This industry conference addressing BIM and Lean was useful in informing the ideal content for BIM, Lean and IPD programs. The event confirmed that Lean should be included to enhance the career prospects of graduates in a fast-changing industry. The attitudes of conference presenters to IPD were consistently positive, despite conference delegates showing less enthusiasm.

While the discussion with conference participants was not guided by a questionnaire that might be used in quantitative research data collecting, key questions were consistently asked. The collective responses to those questions are presented in Table 1.

Item 3(c). On the recommendation of a senior BIM professional, a BIM-knowledgeable academic attended a training course to understand better the course content currently demanded by industry. That exercise confirmed that the program would satisfy the industry's current requirements.

A complex laser-scanning exercise of multiple services to a hospital operating theatre complex was observed. The exercise recorded high-resolution, finely detailed images through block walls in complete darkness, and the decision was taken to include laser-scanning (and photogrammetry) content in any program launched.

Item 3(d). The extensive preparatory research produced findings that formed the basis of recommendations submitted to university management and decisions being made to proceed. To avoid repetition that would inevitably result from presenting study findings regarding what should occur and then describing what the university decided to do, only the institution's decisions are presented below. Each decision taken aligned completely with what study findings indicated should occur and, accordingly, study findings are implicit in the decisions taken, as described below:

- a 'stacked' Master's degree would be presented that could be completed over three trimesters within one year
- Completing all first (trimester) subjects would earn a post-graduate certificate in Building Information Modelling and Integrated Project Delivery (BIM-IPD). This comprised eight five credit point micro-credential subjects, each delivered highly experientially over 18 hours (three days):
  - Foundations of Intelligent Construction
  - Intellectual Property Rights and Introduction to IPD
  - 3D BIM, including Virtual Reality (VR)
  - 4D BIM – Schedule Optimisation
  - 5D BIM – Cost Modelling
  - 6D BIM – Environmental Sustainability Assessment
  - 7D BIM – Facilities Management
  - BIM and Big Data – Geographical Information Systems
- Originally, each micro-credential was constructed with two days dedicated to BIM and half a day each to Lean and IPD (subsequently adjusted, so the IPD and Lean subjects were covered later in the Master's program)
- All the micro-credential assessments would be conducted during face-to-face hours to meet industry requirements
- The second trimester would be dedicated to the post-graduate diploma, comprised of two 10-point six-day subjects and a 20-point 12-day capstone project.
- The third and final trimester of the program would complete the Master's degree, made up of an additional two 10-point six-day subjects and another 20-point 12-day capstone project (subsequently adjusted, so the second trimester addressed four 10-point subjects while the third was dedicated to an internship or research project)

This structure was later adjusted so that all taught subjects were combined into the second trimester, leaving the final trimester for intensive research or a supervised internship.

Table 2 cross-maps the program content recommended by Sacks and Pikas (2013) – widely regarded as the most extensive

Table 2. Mapping program subjects to the schedule of subjects recommended by Sacks and Pikas (2013).

Sacks and Pikas items	Related program subjects
BIM education for construction management.	
Overall construction design management and contracting procedures	Foundations of Intelligent Construction Intellectual Property Rights Integrated Project Delivery content Lean
Facilities maintenance and management	Dedicated micro-credential (five credit points – three days) titled 7D BIM Facilities Management.
Advantages and disadvantages of BIM for design and construction processes	Foundations of Intelligent Construction 3D BIM Lean Capstones
Model progression specification and level of detail concepts	3D BIM Capstones
Changes in management procedures	Foundations of Intelligent Construction Intellectual Property Rights Capstones
Data security	Intellectual Property Rights IPD content
Information integrity	Intellectual Property Rights IPD
Design coordination	3D BIM IPD Lean
Constructability review and analysis	3D BIM Lean IPD Capstones
Management of information flows	3D BIM Capstones
Contractual and legal aspects of BIM implementation	Intellectual Property Rights IPD Lean
BIM standardisation (in organisations and projects)	Foundations of Intelligent Construction
BIM skills and technologies	
Basic BIM operating skills	All micro-credential subjects in P.G. Cert. Capstones
Modelling with standard catalogue elements	3D BIM and 5D BIM Capstones
Creating and modelling with custom elements	3D BIM and 5D BIM Capstones
Massing/solid modelling	Included in the Architecture program
Central databases/information repositories	Discussed and demonstrated in several subjects
Interoperability (file format standards and structure for data mining)	Stressed in micro-credential subjects and again in all theory subjects and capstones
Communication tools, media, channels and feedback	Discussed in several subjects
Ways to store and share information (e.g. cloud computing, networking, spacious room equipment)	Foundations of Intelligent Construction 3D BIM, 4D BIM, 5D BIM, 6D BIM, 7D BIM Capstones
Choosing the right BIM technologies/processes/tools for specific purposes	All micro-credential subjects Capstones
Laser-scanning	Foundations of Intelligent Construction 3D BIM Capstones
BIM functionalities and applications	
Create renderings and representations for aesthetic evaluation	3D BIM Capstones
Rapidly generate multiple design alternatives	3D BIM Capstones
Perform energy analysis	6D BIM Capstones
Perform structural analysis	3D BIM Capstones
Perform automatic take-off and cost estimation	5D BIM Capstones
Check code compliance	3D BIM
Evaluate conformance to program/client value	4D BIM Capstones
Detect clashes	3D BIM Capstones
Perform automatic generation of drawings and documents	3D BIM Capstones
Perform multi-user editing of a single-user model: multi-user viewing of merged or separate multi-discipline models	3D BIM Capstones

(*continued*)

Table 2. Continued.

Sacks and Pikas items	Related program subjects
Rigidly generate and evaluate construction plan alternatives	4D BIM Capstones
Perform automated generation of construction tasks	4D BIM Capstones
Perform discrete event simulation	4D BIM Capstones
Perform 4D visualisation of construction schedules	4D BIM Capstones
Monitor and visualise progress status	4D BIM Capstones
Export data for computer-controlled fabrication	BIM and Maximising Value (Master's)
Integrate with project partner (in the supply chain) databases	Post-graduate diploma and Master's subjects

completed study in the BIM field during the past decade – with that included in the finalised suite of BIM-IPD subjects.

Phase 4 – final approvals and launch

Items 4(a) and 4(b) cover two internal approvals and one for CRICOS codes to allow offering programs to international students. Item 4(c) involved appointing lecturers (eight from industry and two from the faculty) for the launch and having the adjuncts write their course material in parallel with the approval processes.

Item 4(d) involved configuring a BIM laboratory established for 12 students to meet the university's low student-to-staff ratio guidelines. Cognizant of the program's strong emphasis on practical experience, the technology was arranged in four groups of three standard university IT specification workstations. Two of these three-desk pods were equipped with a high-specification computer and Bluetooth VR equipment.

Items 4(c), 4(f) and 4(g) are self-explanatory and respectively involved:

- Procuring appropriate industry-relevant *OpenBIM* compatible and IFC-friendly BIM-related software and licenses
- Arranging industry professionals to teach launch program subjects
- Testing technology and uploading and testing a VR model of an extension to a building on campus

Discussion and conclusions

The format of this paper necessitated much of what might normally be presented in a separate discussion section being included with the main content before presenting conclusions. The final points of discussion are presented, with some conclusions, in this section.

Commencing investigation into the viability of introducing BIM education with a review of literature proved insightful and might prudently be replicated by universities in similar situations. Having the bSA president and two experienced BIM professionals attend the first industry discussion guided considerable value in forming an investigation strategy and finalising the curriculum structure. A similar engagement with relevant professional practitioners is strongly recommended for other universities considering new programs, especially with Built Environment-related programs.

The bSA-supported decision to include Intellectual Property Rights, even in the context of the highly collaborative, no-blame culture of BIM-IPD projects, was taken with a full understanding of the reality of the constant potential for construction project disputes.

Employing industry professionals as adjunct lecturers is recommended for universities launching programs involving rapidly changing technology. This helps ensure content currency and exposes students to potential employers, to the benefit of both. The early decision to not only rely on academic research in formulating new programs, but also to use industry research to inform program direction, content and delivery models, proved immensely valuable and is strongly recommended to universities planning to launch similar new programs.

The program that resulted from the research covered in this exploratory case study was structured as a three-component stackable Master's degree to appeal to both industry professionals seeking to upskill and graduates of construction programs wanting to study BIM-IPD-Lean to enhance their employment potential. The program comprises a post-graduate certificate (eight 18-hour micro-credential subjects), a post-graduate diploma, and a Master's degree, completed in three single trimester stages within one year.

The adopted phased model of progress is highly recommended, informed by relevant published academic research and advice from respected practicing industry professionals and professional institutions.

The program that resulted from this research-informed approach fills a gap in construction education demand, and its development has provided a clear model for an agile project management approach (seven months from concept until readiness to formal launch) to curriculum research and program development for the benefit of all universities in the international education community, their students and the industries they serve.

A major challenge of the study was identified early and the answer to that issue was identified in data from industry members. The challenge was ensuring that, in meeting industry needs, the university in no way diminished its academic rigour regarding programs. This was addressed to the satisfaction of the institution's Program Subject Review Committee by the following:

- All key industry requirements were delivered primarily in the post-graduate certificate component of the program, including a high level of practical work using various software packages and completion of assessment tasks during the three-day duration of each micro-credential (five credit points) subject
- Each subject for the second semester ($n = 4$) was delivered intensively over two three-day periods with an end-of-course assessment

- The final semester leading to the Master's degree involved a choice of internship in a reputed BIM professional organisation with close supervision by a recognised BIM professional and the completion of an 8,500-10,000-word report or a supervised research project culminating in the submission of a 12,500-15,000-word thesis.

The program continues to be coordinated by a full-time academic with BIM experience. In addition, adjunct lecturers are strongly encouraged to complete the post-graduate certificate program themselves to understand other subjects better and facilitate optimum subject integration and collaboration with lecturers. To date, 50 percent of adjunct lecturers have accepted this offer and are in the process of completing the program, and all others have committed to completing the program when business commitments permit.

Key outcomes

At the time of writing, 53 students had graduated from the program. This number reflects Bond's low student-to-teacher ratio and the decision to limit numbers in the early semesters to test the program's effectiveness. Also, the program was placed on hold during the Covid-19 pandemic because of the difficulty of delivering such a complex and technical program online.

To the best of the current course coordinator's knowledge, every program graduate was employed as a BIM professional within two months of graduation, with some employed during studies and others immediately after graduation. Course adjunct lecturers employed several due to strong recommendations from those lecturers.

Study limitation

The literature review and industry research described in this study aimed to collect data from which useful conclusions could be reached regarding the design and delivery of an innovative university program addressing a highly technical, rapidly emerging and industry-relevant topic. There was no intention at the time the study was conducted of authoring an article for an academic journal publication. That idea emerged primarily when interest in the unusual program structure became more universally known, and industry and academic interest in what had been done became evident. As a consequence of this background, this paper has been presented in a manner that the authors trust will provide the clearest possible explanation of the process in the circumstances, but the authors do recognise that the paper might be weaker for how it is eventuated.

Despite all intentions to the contrary, the study is limited by the lead author being the university's project manager; hence, the potential for unintended bias.

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TBA

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