RMIT UNIVERSITY

Learning and Teaching Investment Fund final report

Global Passport through Co-integration of Construction Immersive Environments

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Infographic Global Passport through Co-integration of Construction Immersive Environments

Strategic objectives addressed:
This project is in strict alignment with RMIT strategic plan with Goal 1: Global in attitude, action and presence, offering our students a global passport to learning and work. It matches very well with Priority 1, Priority 2, Priority 3 and Priority 4;

> *Priority 1: Develop an integrated global strategy to guide development of our global presence*
>
> *Priority 2: Grow and diversify RMITs network of teaching, research and industry partnerships in selected city locations across the world. These partnerships will support our high impact areas of education and research by increasing the quality and quantity of offshore education*
>
> *Priority 3: Define and deliver an RMIT student experience that is characterised by its global engagement, international mobility and cross cultural opportunities.*
>
> *Priority 4: Support global engagement by all RMIT staff by initiating development and improvements to internationalise academic programs*

Coupled with this the project also focuses on the following 2014 LTIF priority:

> *.. designing or redesigning sustainable programs for onshore and offshore delivery, including flexible delivery*

The College and the School work plans have objectives to increase and improve international offshore delivery and this project seeks to achieve this. The 2013 Program Annual Review (PARS) for the School of Property, Construction and Project Management(PCPM) identified 3 Priority Actions. One of those three priorities was International Development and growing our programs offshore. The School has a strong presence in Singapore and Hong Kong. The most recent offshore agreement is the CAP program with China University of Mining and Technology. The School is seeking to increase offshore delivery in Europe and China. and is focussed on offshore delivery of programs. We have initiated offshore delivery of our undergraduate and postgraduate programs in various locations including; China, Vietnam, Hong Kong and Singapore. We are seeking to increase our offshore delivery in Europe as well.

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Funding scheme	LTIF contestable	X

1. Executive summary

The delivery of construction projects is undergoing a major shift internationally with increasing utilisation of advanced information technologies. Increasingly in practice, immersive technology is being utilised to blur the lines between the physical world and the virtual world to design, visualise, simulate, deliver and manage the built environment. A necessary part of this 'smarter' world is the creation, use and management of Building Information Models (BIM). A Building Information Model is a virtual model of the proposed facility (building/asset) which has data and information on the physical properties (materials, components, systems) and the nonphysical properties (where to procure, when to maintain, relationships to other elements etc). This integrated data repository ('Model') allows virtual analysis and simulations of the proposed design and associated construction methodologies prior to and during physical construction. The use of building information modelling is spreading rapidly through the global design and construction industry and architects, engineers and contractors in Australia are no exception. Therefore our property, construction and project management graduates are potentially entering an ever changing workforce that will in the future require a 'smarter' way of working.

> *'Change is sweeping the globe. Project Teams are benefitting from faster communications, smaller, more powerful and mobile computers, robust digital modelling tools and a transformative shift towards integrated project delivery processes, all of which are generating positive outcomes, efficiencies and benefits unimaginable just a few years ago'*

Our goal is to ensure that our graduates will have the theoretical knowledge and technical skills to enable them to work effectively as a construction management professional and to critically engage with contemporary construction management theory, situating their learning in the wider industry context, we therefore need to establish some form of commitment to Building Information Modelling and take leadership in Australia. This project identified the theory and practice underpinning curriculum redesign incorporating BIM into programs, the discourse in curriculum design and the nature of these changes in the local market as well as the response to these changes. Conventional approaches to curriculum design and traditional delivery modes of lectures may no longer be suitable for nurturing future construction professionals who should excel in the digital world and who will need to be innovative in their ability to embrace data and information modelling, analysis and management to increase construction project productivity. The attitudes to and extent of introducing BIM teaching into current curricula ranged from the mere acknowledgement of the presence of BIM to the embracement of BIM into all elements of the program and across disciplines. Research into the current state of BIM curricula, which formed the basis of the following categorisation, addressed mainly the US context (Barison & Santos, 2010). Models of curriculum design were categorised as either detached, aware, infused, combined and embedded with or without a cross-disciplinary component. In contrast to the models for integrating sustainability education into university curricula, the review of the literature did not find any examples in which BIM was offered as a specialisation option or in which a second BIM Construction Management course was offered as a separate program.

Project achievements:

1. Development of resources to guide the School in curriculum redesign in BIM Education
2. Contribution to the theoretical discourse on the Threshold Concept
3. Design of a theory based Student Threshold Capability Framework
4. Design of a curriculum redesign process for Global Co-integration (Phase 1) with broad applicability to disciplines with external professional accrediting bodies and recommendations of principles specific to construction management program delivery
5. Evaluation of the Framework through 25 in depth interviews with key stakeholder groups
6. Analysis of an exemplary international case study with curriculum mapping to Framework
7. Development of a modified Student Threshold Capability Framework for Digital construction project management curriculum based upon empirical analysis
8. Initiation of resources database for PCPM staff on Digital educational technologies
9. Development of videos of staff and industry employers sharing their experiences

2. Outcomes

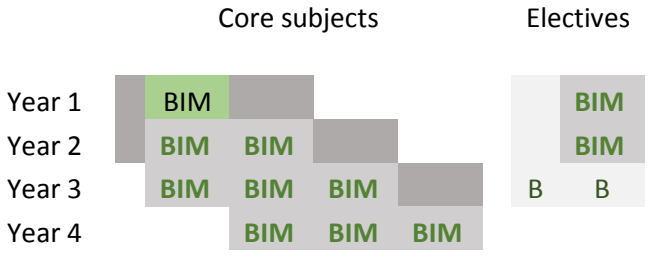
Outcome 1: Resources to guide the School in curriculum redesign in BIM Education

This literature review provides an up to date overview of BIM education with a particular focus on the approaches to curriculum design. Formal BIM accreditation criteria from Degree Accrediting Professional Bodies appears to be still missing and it has been the BIM triggered transformation of the architecture, engineering and construction management (AEC) sector that has been driving a change in curricula amongst the AEC schools globally (Hyatt 2011). Hence, curriculum guides have been published that included Building Information Modelling (BIM) and the teaching of BIM has becoming increasingly popular in higher education (Joannides, Olbina & Issa, 2012; Wu & Issa, 2014). It was suggested that construction courses should stress BIM as a methodological rather than mere technological tool.

In terms of BIM curriculum content, BIM in the context of internationalisation was rarely a subject of the discussion. There was agreement that BIM education should cover all aspects of BIM, namely people/culture/ project team roles (psychological and social skills), processes/ management processes (conceptual skills) and technology/software skills needed to be considered in a balanced manner (Barison & Santos, 2010; BIM Academic Forum UK, 2013; Macdonald, 2011; Sacks & Pikas, 2013). This goal did not seem to have yet been achieved in the US. Examining the syllabi of 18 BIM courses of seven US universities Sacks (Sacks & Pikas 2013) found that the courses emphasised technological and collaborative learning and that management specific BIM topics, e.g. standardisation, contractual aspects, data and information security as well as change management, were neglected. Such a comprehensive approach to content and curriculum design is espoused by all leading authorities and yet these capabilities around core aspects of construction management theory (such as construction information flow, procurement, legal, contractual, regulatory, subcontractor management, business management and strategy and leadership/change management) are not yet evident in curriculum. Examples from the UK, US, Australia, New Zealand and Israel were included in the review.

With regards to the process of developing curricula in universities, researchers agreed that each institution would need to develop its own approach, based on current BIM content in the curriculum, available infrastructure and current staff skills (Williams and Lees, 2009, p8 as cited in BIM Academic Forum UK, 2013). Learning outcomes and targets levels should also be determined on the basis of local industry needs and the students' existing knowledge (Sacks & Pikas, 2013). The attitudes to and extent of introducing BIM teaching into current curricula ranged from the mere acknowledgement of the presence of BIM to the embracement of BIM into all elements of the program and across disciplines and where BIM evolves into a 'lingua franca'. Research into the current state of BIM curricula, which formed the basis of the following categorisation, addressed mainly the US context (Barison & Santos, 2010). Models of curriculum design were identified and categorised as either detached, aware, infused, combined and embedded with or without a cross-disciplinary component.

Embedded - BIM becomes lingua franca



Curriculum model – Embedded

Outcome 2 Contribution to the theoretical discourse on Threshold concept

The literature review in Section 2 raised interesting issues in relation to both curriculum design or redesign to include BIM content and BIM learning outcomes or threshold capabilities. The review is organised into four main sections; a background to the underlying concepts in the current discourse of curriculum development, outcomes based education and learning outcomes, the threshold concept theory and the process of curriculum design.

Threshold concepts were “critical points in a student’s learning” (Barradell, 2012; p268). The Threshold concept theory is explored in more detail in this report. Despite the growing popularity of the Threshold Concept theory since its conception a decade ago, it was critiqued for its lack of maturity (Tight, 2014b). Due to the focus of the threshold concept theory to disciplinary content, its application to outcome-based curricula was considered to be strained. Recent efforts were made to better integrate the threshold concept into current curriculum design approaches.

In 2011 in Australia there was a national project funded by the Office of Learning and Teaching, “Learning and Teaching Academic Standards Project LTAS”, which addressed discipline specific competencies. The Building discipline was part of the LTAS project and was one such discipline that developed such competencies. Threshold Learning Outcomes (TLOs) were developed. Professor London was a member of the LTAS Building Discipline Reference Group representing the industry professional association Chartered Institute of Building who is an international accrediting organisation. Upon completion of a bachelor degree in building and construction, graduates will be able to:

1. *integrate and evaluate the fundamental principles and technical knowledge of building and construction technology, management, economics and law*
2. *identify and resolve typical building challenges with limited guidance, employing appropriate evidence-based problem-solving and decision-making methodologies*
3. *critically and creatively reflect on personal behaviours and capabilities in the context of entry to professional practice*
4. *interpret and negotiate building and construction information, instructions and ideas with various project stakeholders*
5. *research and develop methods and strategies for the procurement and delivery of contemporary construction work*
6. *demonstrate an integrated understanding of both the theory and practice of building and construction based on experience. (LTAS, 2011)*

Anecdotally there have been criticisms that the TLOs are too high level. The thresholds concept theory has been applied in disciplines including the sciences, health care, literature business, law and social studies (Tight, 2014b). While it would be beyond the scope of this paper to review all applications, one Australian example in engineering education is presented in the review. An Australian team of educators at the University of Western Australia combined the threshold concept with capability and variation theory into the Threshold Capability Integrated Theoretical Framework (Baillie et al., 2012a). For Bailie et al. (2012) the thresholds concept had the advantage of making apparent implicit learning concepts which facilitated the focus on the most important steps in the students’ learning progress, the most appropriate educational experience and the best assessment methods (Baillie et al., 2012a). Capability theory is concerned with teaching students capabilities to deal with unforeseeable future events and problems (Bowden, 2004). Capabilities were merged with the threshold concept as the elements that were deemed troublesome were not always disciplinary concepts but included capabilities to cope with new situations (Baillie, Bowden & Meyer, 2013). While in the threshold concept theory the disciplinary knowledge content is driving the structure of a curriculum, curriculum design based on capability theory focusses more on situational and progressive learning and the requirement of fundamental cognitive attitudes that are seen to be essential in becoming successful professionals (Åkerlind, McKenzie & Lupton, 2014; Bowden, 2004). Based on the Threshold Capability Integrated Theoretical Framework the following questions guide a curriculum design process:

1. "What should the learner be capable of doing at the end, given the need to deal with an unknown future?

2. What threshold concepts are important to understand to enable the development of such capability?

3. What kinds of learning experiences and in what combination would best assist the learner to develop interim threshold capabilities and ultimately build on them to develop the capability to handle the unknown future after graduation?

4. How can the learning environment be best arranged to provide access to those optimal capability development experiences?

5. How can the differing needs of individual students be catered for?

6. What, specifically, is the role of teachers in supporting such learning by students?

7. What kinds of assessment of student learning will motivate learning of the kind desired and authentically measure the levels of achievement of the intended learning outcomes?"(Baillie, Bowden & Meyer, 2013, p237).

We addressed specifically Question 1 and 2 in this project.

Outcome 3 Student Threshold Capability Framework

We developed a preliminary Student Threshold Capability Framework based upon the literature review. The threshold concepts in relation to different learning categories – for example learning to become a BIM manager, thinking and understanding like a BIM manager and shaping the world as a BIM manager, (Baillie et al, 2012). In the first instance we are guided by past work that identified critical points and thresholds in BIM adoption in Australian firms (London et al, 2009). We have used London et al (2009) earlier research in this area on adoption, pathways and thresholds to develop a framework so that we have a starting point for our stakeholders to respond to. The first threshold is "introductory" and is termed the 'Cognition Level' and is concerned with learning to think about BIM environments and develop basic capabilities to operate within a BIM environment as a construction manager. The next level is considered 'advanced' and is termed the ' Compatibility Level' and is concerned with learning to think, understand and act like a construction manager who integrates people, systems and processes within BIM environments, i.e. an understanding of the ability of various systems to be able to coexist harmoniously. The third level is 'application' and is termed the 'Connectivity Level' and is concerned with learning to effectively collaborate with others involved in BIM projects and demonstrate intellectual independence and autonomy to solve problems with in BIM environments. The final level is a 'self-applied' and is termed the 'Integration Level' and is concerned with learning about what it means to lead BIM projects and the organisational environments required and how to shape the world for multiple and diverse connections. These four levels may correspond broadly to the four years of instruction in our program.

Further to this philosophical conception of these four threshold concepts of cognition, compatibility, connectivity and integration there are themes and content that a learner should be able to do which we have synthesised and distilled from the literature. We have synthesised the BIM education literature content as well as reflecting upon RMIT's strategic goals in relation to international education and identified the following key five thematic content areas:

- Fundamental principles
- Technical skills
- Construction project management skills
- Strategic organisational behaviours
- Global market context

The following figure presents the draft of a Threshold Capability for BIM in Construction project management curriculum with an initial consideration of some of the detail content topics/areas within each of the five thematic areas. At this stage we did not wish to pre-empt our consultations with our stakeholders but we also didn't wish to go to our various constituents with a "blank sheet"; since there has been extensive research on this topic as well as experiences from emerging industry practice to draw upon.

Threshold Capability for BIM in a Construction Project Management Curriculum

Threshold concepts and capabilities are certain concepts and capabilities within a field that are required to be held to ensure mastery of a particular knowledge domain.
Threshold concepts and capabilities are transformative, troublesome, irreversible and integrative.

THEMES	Introductory: Cognition Level	Advanced: Compatibility Level	Application: Connectivity Level	Integration - Self Applied: Capstones
	Learning to think about BIM environments and develop basic capabilities to operate within a BIM environment as a construction manager.	learning to think, understand and act like a construction manager who integrates people, systems and processes within BIM environments.	Learning to effectively collaborate with others involved in BIM projects and demonstrate intellectual independence and autonomy to solve problems with in BIM environments.	Learning to lead BIM projects and organisational environments by shaping the world for multiple and diverse connections of people, organisations and systems .
	Year 1	Year 2	Year 3	Year 4
FUNDAMENTAL PRINCIPLES	Generic: Concept, Definition, Trends , Stakeholders, Implementation, Project Phases, Scope, Purpose, Conflicts	CM /QS Discipline principles application: safety, quantities, visualisation and communication, scheduling, clash detection, site planning logistics, Project Method Statements, tendering and procurement, constructability	Examples of emerging theories	final year capstone experience
TECHNICAL SKILLS	Skills: Opening, Notations, Sharing, Importing, Exporting, Software: AutoCAD, Google Sketch, REVIT, Navisworks, Infraworks	Skills: Clash detection analysis, BoQ generation, Generation PMS, Proof of Concept/Re-engineering/VE, Design>Prefab, Construction sequencing, MEP trade coordination model sharing. Software: Autodesk Quantity Take off, Bentley, Solibri, VICO, Navisworks, Infraworks	Exemplars of major construction projects	
CONSTRUCTION PROJECT MANAGEMENT SKILLS	Simple team environments: Collaboration within the team and organisation, managing the environment	Complex collaborative environments: large scale projects or multi project contexts, leading the environment, virtual teams	Exemplars of construction organisations in networks that are highly connected (Connectivity Level) examples of entrepreneurship	
STRATEGIC ORGANISATIONAL BEHAVIOURS	CBA of BIM implementation, simple decision making, identification of purpose and small firm strategy, simple Model Ownership & IP rights, BIM Management Project Plans	Strategic Business Case Planning, Complex decision making, diverse strategies of Model Ownership, staff training - project start up (Level 1) , systems integration (Level 2) and knowledge management (level 3); BIM Operational Plans	Exemplars of HR training plans, global systems integration and business models of BIM implementation	
GLOBAL MARKET CONTEXT	Data types and management, data and information regulatory and policy framework, standards and protocols, national organisations (BuildSmart), Australian accrediting bodies standards/expectations, regional norms, values and accepted practices; beginning to understand cultural contexts and how this shapes BIM implementation	Inter-operability protocols (history of STEP/BIM/), international organisations, international accrediting bodies expectations/standards, reflexive approach to balancing the tension between local context, different ways of doing things in different countries but still operating in a multi country project team environment with various standards;	Case studies of companies that have a corporate social responsibility policy that explicitly demonstrates respect and enhancement of diversity	

"A threshold concept can be considered as akin to a portal, opening up a new and previously inaccessible way of thinking about something."

Meyer, J.H.F. and Land, R. (2003) Threshold concepts and troublesome knowledge: linkages to ways of thinking and practising, In: Rust, C. (ed.), Improving Student Learning - Theory and Practice Ten Years On. Oxford: Oxford Centre for Staff and Learning Development (OCSLD), pp 412-424.

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Student Threshold Capability Framework derived from Literature

Outcome 4 Curriculum Redesign Process and Recommendations of Principles for Global Co-integration

We have developed a Framework with Guiding Principles on curriculum redesign accounting for global foundational skills and knowledge as well as local context and variations specifically targeting our construction management program. However this is clearly applicable to any programs that have similar characteristics in particular in relation to professional accreditation, international institutional partnership agreements and industry focussed, merging new digital technologies into curriculum – and with the overarching problem of curriculum redesign to respond to an paradigm shift in the industry where graduates are placed. Hence it has generic qualities and can be easily adapted by others at RMIT. (see figure Global co Integration Model).

We developed with various inputs (industry leaders, literature, academic leaders, professional accrediting bodies) threshold concepts in relation to different learning categories – for example learning to become a BIM manager, thinking and understanding like a BIM manager and shaping the world as a BIM manager, (Baillie et al, 2012). We developed a robust understanding from first principles the nature of the emerging digital technological phenomenon referred to as Building Information Modelling and the implications for introducing this into curriculum. We explored this using the educational approach of henomenography (with insights from phenomenology). Qualitative data was collected to provide in-depth information on the expectations, ideas, insights, attitudes and

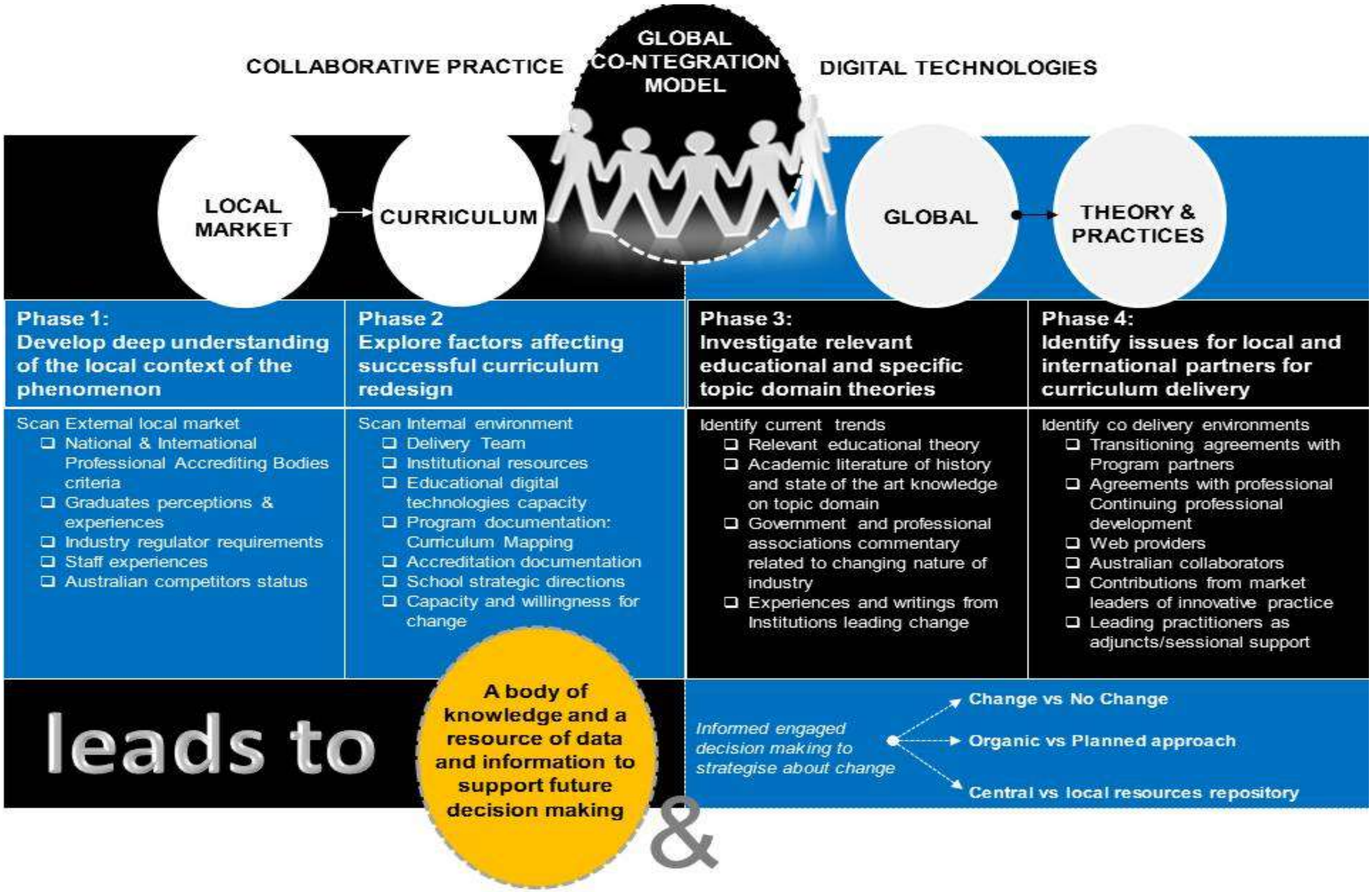
experiences of the key stakeholder groups of BIM education in the School of Property, Construction and Project Management. Stakeholders who informed us about this phenomenon included partner universities, employers, professional accrediting bodies, teaching staff and graduates. We developed a comprehensive understanding of numerous diverse experiences, perspectives and attitudes including issues, challenges, context, successes, internationalisation, globalisation etc.

The project was originally framed in principle with a phenomenological research design, which according to O'Leary (2009) is the 'study of phenomena as they present themselves in a direct experience.' This is not a research project however we validated our work through a rigorous approach and developed a robust methodology for validation on curriculum redesign. This project is very much aligned to the teaching-research nexus model. Admittedly, within phenomenological inquiry there are quite wide ranging differing definitions of its nature and tasks. Given the extraordinary philosophical roots and depth of writings on this methodology originating from Husserl in "Investigations of Logic" (1900) to contributions from his assistants and colleagues Heidegger, Scheler, Jaspers to the French contingent Sartre, Merleau- Ponty and de Beauvior and even later in Derrida's deconstruction theory –reducing it to a mere paragraph of a definition does little justice to the movement and its lengthy European tradition. According to O'Leary 'There are various forms of phenomenology including social, philosophical, existential, empirical, hermeneutical, psychological and transcendental, which are all highly theory-dependent, make it exceedingly difficult to succinctly describe its field and/or its methods." The researchers who adhere to this methodology are diverse in their interests, issues and application (Moran, 2000). There are important tenets that we can distil.

Phenomenology is about social construction; people and their experiences are important to constructing our awareness and knowledge about certain phenomenon. Also it is inter-subjective, that is, we experience the world with and through others. Therefore a key premise is that to make sense of the phenomenon we need to see and understand it through the lived direct experiences of those who interact with the phenomenon. It is important that we suspend assumptions about causes, truth-value, reality or appearances and attempt to describe the ideas, perceptions and awareness that people have of the phenomenon. Throughout much of the writings on phenomenology one of the most important characteristics of this approach that is emphasised is that we must try to get to the truth of the matter by describing the phenomenon as it appears to the experiencer; trying to avoid misconstructions and impositions in advance. An important theme is that there should be descriptions first and that explanations should not come until the phenomenon has been understood from within (Moran, 2000).

In our world of curriculum design an important consideration is that our 'individuals' tend to form stakeholder groups including staff, current students, alumni, employers, accrediting bodies and other institutions and so dealing with the idea of celebrating the individual vs the common voice of the collective is important in this project. To this end phenomenography is an approach that is deployed for education projects that we have found useful in solving some of the issues that we have around collective meaning vs individual experience; our pre reflections on the phenomenon through the Threshold framework we developed and our ultimate aim to develop some outcomes and recommendations rather than a focus on the meanings that we may place on our empirical observations and the development and interpretation of constructs around our phenomenon.

Phenomenography is a research approach specifically "designed to answer certain questions about thinking and learning" (Marton 1986, p. 28). Based on the work of Swedish educator Marton (1986), phenomenography explores the variations in understanding of a phenomenon among different groups of people (Larsson & Holmström, 2007) and is frequently used in research in higher education (Åkerlind, McKenzie & Lupton, 2014; Entwistle, 1997). The focus of a phenomenographic approach is on the collective rather than on the individual. The aim is to convey the common experiences or perceptions of a phenomenon within a group and to compare and contrast these to the common experiences or perceptions of other groups of people in order to find categories or relationships that are linked logically and often hierarchically (Åkerlind, 2012). Categories are not preconceived but emerge from the data (Åkerlind, 2012). There are examples of the use of a phenomenographic approach in Australia including; the exploration of the understanding of academics of generic graduate attributes (Barrie, 2007) and the development of a curriculum of a two-year engineering foundation course (Åkerlind, McKenzie & Lupton, 2014; Baillie et al., 2012a).



Global co-integration Model

We also developed recommendations as guiding principles specifically for Digital Construction Management Curriculum Redesign as indicated by the following table.

Digital Construction Management	Recommendations
Foster academic leadership	*It is recommended that the Delivery Team evaluate the decision to transform and change the curriculum with due consideration of the Threshold Capabilities Framework as a guideline and develop a common vision.* RMIT is a leader in offshore and international education and is the national leader and one of the international leaders in construction project management education and so should take a lead in the implementation of BIM curriculum in undergraduate construction management program.
Support deep engagement	*It is recommended that the design of a transition plan over 3-5 years be considered to introduce BIM curriculum in the undergraduate construction management program that accommodates both an organic evolutionary and planned structured approach.* Staff already deliver some education in Building Information Modelling and an integrated approach would provide a clear framework for staff to enhance the student experience and improve graduate outcomes in this emerging area.
Initiate resilience	*It is recommended that staff continue to approach the development of Building Information Modelling skills to prepare graduates for industry readiness with due consideration of the local market and ensure future delivery still takes into consideration that the industry has varying levels of adoption and that graduates are resilient to changing conditions.*
Prepared for change	*It is recommended that University support for advanced information technologies in Learning and Teaching requirements be made known in specific detail to support a student – teacher enabled IT environment.* The current IT environment does not readily support such an innovative curriculum and steps need to be taken in service delivery before a feasible and sustainable curriculum change can be undertaken.
Acquire technologies	*It is recommended that coupled with individual local resources that staff currently develop that a School wide central resources repository be created to support delivery including a Model and software applications licenses.* Availability of enhanced detailed Building Information Models to support teaching programs is required and it is recommended that a detailed Model is obtained to support staff to integrate their delivery.
Build capacity	*It is recommended that an analysis of capacity to deliver be mapped to overall transition plan and that steps be taken to upskill and/or recruit staff where desired and required.*
Enhance local cooperative delivery	*It is recommended that consideration be given to exploring opportunities for various arrangements for co delivery with professional associations and alignment with continuing professional development as it is developing to support credit for prior learning opportunities.*
Initiate targetted partnerships	*It is recommended that following in the current School practice of strength in industry connections that partnership(s) be developed with industry organizations, market leaders, software vendors and leading international institutions who are undertaking innovative BIM implementation.*
Pooling resources	*It is recommended that staff within the Delivery Team consider pooling resource development and support be identified for further enhancement to existing materials.*

Outcome 5 Evaluation of Framework

We canvassed the knowledge and experiences of a range of stakeholders on Building Information Modelling and present a detailed description and analysis of 25 in depth interviews with past graduates (4), employers (9), national and international accrediting bodies (3), current staff (6) and academics from international institutions (3). We identified various common themes and different viewpoints which provides us with a snapshot of current understandings and positions.

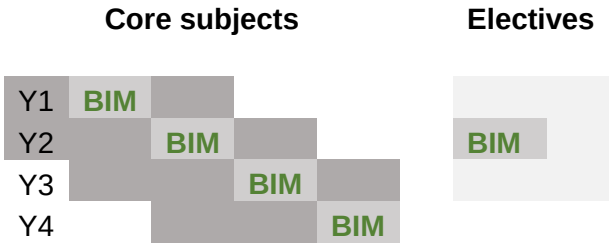
We also held meetings with members of the Project Steering Committee (2 formal meetings and then 3 follow up meetings with individuals on the Committee) to discuss the project, issues, trends and specific details on the Framework. The various insights presented in this report will be a useful resource for some of staff in the Delivery Teams in the School.

Outcome 6 International Institution Case Studies

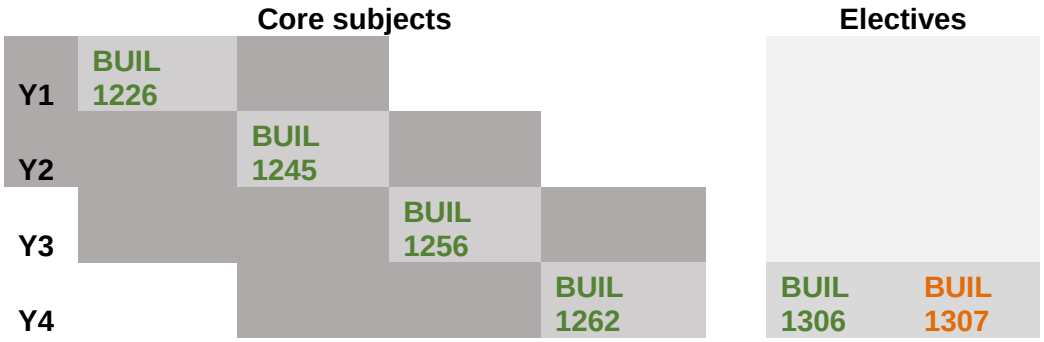
We evaluated and mapped our program in relation to the various BIM integration curriculum models including; Detached, Aware, Infused, Combined, Stream-lined and Embedded.

BIM teaching in BH114: Bachelor of Applied Science (Construction Management) (Honours) closely resembles that of the “infused” approach where there is integration of BIM content in courses across each year level.

Infused/adapted/ intrinsic



The following map identifies various courses where some Building Information Modelling concepts are currently presented.



We also developed a comprehensive mapping of Auburn University’s curriculum (refer to following figure). More detailed discussion can be found in the relevant section in the report.

	Yr 1 sem 1 Freshman	Yr 1 sem 2	Yr 2 sem 1 Sophomore	Yr 2 sem 2	Yr 3 sem 1 Junior	Yr 3 sem 2	Yr 4 sem 1 Senior	Yr 4 sem 2
Core subjects						ENGL 3040 or 3080		
			BSCI 2400 Structures for Builders I		BSCI 3420 Structures for Builders II	BSCI 3430 Structures for Builders III	**BSCI 4601 Project Control III CIT Lab**	
	BSCI1100 Intro to Construction	BSCI 2300 Materials & Methods		**BSCI2200 Construction Communication**	BSCI 3500/ 3550 Construction Info Technology I	BSCI4700 Mechanical Systems in Buildings	BSCI4750 Electrical Systems in Buildings	BSCI4990 Thesis - voluntary BIM based
		BSCI 2100 Intro to Sust. Constr.			BSCI3600 Project Controls II	**BSCI3650 Project Controls II**	BSCI4600 Project Controls III	BSCI 4850 ConstructionLaw & Risk Mngt.
					BSCI3700 Construction Safety	MNGT3810 Management Foundations	BSCI4800 Contracting Business	
Electives							BSCI 4860 Advanced Information and Communication Technology for Construction	Business and Construction Management electives

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Outcome 7 Threshold Capability Framework for Digital construction project management curriculum

We developed the original Framework with various inputs from staff, graduates, industry leaders, academic leaders, professional accrediting bodies and refined the threshold concepts in relation to the different learning categories –learning to become a BIM manager, thinking and understanding like a BIM manager and shaping the world as a BIM manager (refer to following figure).

Student Threshold Capability Framework for Digital Construction Project Management Curriculum

Threshold concepts and capabilities are certain concepts and capabilities within a field that are required to be held to ensure mastery of a particular knowledge domain.
Threshold concepts and capabilities are transformative, troublesome, irreversible and integrative.

THEMES	**Introductory: Cognition Threshold** Learning to think about BIM environments and develop basic capabilities to operate within a BIM environment as a construction manager.	**Advanced: Compatability Threshold** Learning to think, understand and act like a construction manager who leads construction projects and integrates people, systems and processes within BIM environments and understands impacts and challenges of compabitibility of people/systems and processes.	**Application: Collaboration Threshold** Learning to understand implications of collaboration and basic skills to effectively collaborate with others involved in BIM projects and demonstrate intellectual independence and autonomy to solve problems within BIM environments.	**Connectivity - Self Applied: Capstones** Learning to lead BIM projects and organisational environments by shaping the world for multiple and diverse connections of people, organisations and systems; introduction to concept of resilience capability for change. Opportunities for electives and research projects
	Year 1	**Year 2**	**Year 3**	**Year 4**
FUNDAMENTAL PRINCIPLES				
	Introduction to the concept of Virtual Construction and BIM. Background information includes Definition, Trends, Stakeholders, Purpose, Implementation, Project Phases, Scope and Interdisciplinary conflicts	Introduction to use of BIM specifically by CM /QS disciplines: safety, quantities, sustainability, project planning, visualisation and communication tool, scheduling, clash detection	Development of Advanced CM /QS Discipline principles application: production planning, lean construction, scheduling, site planning logistics, Project Method Statements, tendering and procurement, constructability	
TECHNICAL SKILLS				
	Introduction to data; type, structure and management. Introduction to digital skills for BIM management: Opening, Notations, Sharing, Importing, Exporting, Software: AutoCAD, Sketchup, REVIT, Navisworks	Introduction to skills for BIM production planning ; clash detection, design reviews, model sharing, trade coordination; understanding of data security and access and implications on information flow and workflow; data object libraries. Introduction to CostX, Solibri	Development of advanced Skills: Estimating and BoQ generation, Generation PMS, Introduction to more advanced concepts and skills required: Proof of Concept/Re-engineering/VE, Design>Prefab, Construction sequencing. Consolidation of software use: CostX, Solibri, VICO, Navisworks etc and import/export implications. Data loss and interoperability.	
CONSTRUCTION PROJECT MANAGEMENT SKILLS				
	Introduction to the idea of use of a Building Information Model as a tool for communication and coordination within simple projects and teams: relating BIM to integrated supply chains, identification of actors in the supply chain and team collaboration, design management, subcontractors and stakeholders	Introduction to idea of using Building Information Modelling as a methodology to enhance project collaboration; impacts of collaboration on Model ownership and legal implications; BIM as part of a contract. Introduction to advanced concepts in using BIM in tendering and procurement, various	Development of advanced concepts in using BIM in strategic procurement; off site manufacturing; client management; complex large scale projects and collaborative environments; opportunities in multi project environments and program management	
STRATEGIC ORGANISATIONAL BEHAVIOURS				
	Introduction to the Value Proposition for Contractors, subcontractors, Materials Suppliers, Designers, Clients and Regulatory Bodies.	Introduction to implications ofintroducing BIM in organisations; change management, staff training, BIM tools; systems integration, knowledge management; BIM Operational Plans	Introduction and development of advanced concepts of BIM and construction business; exemplars of HR training plans, global systems integration and business models of BIM implementation; BIM and change management	
GLOBAL MARKET CONTEXT				
	Basic introduction to history of BIM within international context; introduce concept of national standards and protocols, national organisations (BuildSmart), Australian accrediting bodies standards/expectations, BIM in relation to local construction processes; regional norms, values and accepted practices	Introduction to opportunities of using BIM within international construction environments, international accrediting bodies expectations/standards, balancing the tension between local context and universal standards, different ways of doing things in different countries but still operating in a multi country project team environment with various standards;	Development of advanced concepts of managing across different countries on projects; multi disciplinary teams; implications of different cultures on team performance; international sourcing and procurement of materials/building systems/services; outsourcing ; ethical use	

final year capstone experience

"A threshold concept can be considered as akin to a portal, opening up a new and previously inaccessible way of thinking about something."

Meyer, J.H.F. and Land, R. (2003) Threshold concepts and troublesome knowledge: linkages to ways of thinking and practising,In: Rust, C. (ed.), Improving Student Learning - Theory and Practice Ten Years On. Oxford: Oxford Centre for Staff and Learning Development (OCSLD), pp 412-424.

Modified Student Threshold Capability Framework

Outcome 8 Initiation of database for staff on Digital educational technologies to support BIM teaching

Digital Educational Technologies

We have identified five types of digital resources that could support BIM teaching:

1. Building Information Models to introduce and showcase concepts and principles

2. Building Information Models to introduce and develop skills which would require controlled access to the Models by students and and have high levels of interactivity

3. Resource materials to showcase exemplar projects (typically videos)

4. Resources materials to explain and describe particular concepts and show how models can be used and thus enable skill development through self direction (typically videos coupled with other material and testing schemas)

5. Research literature describing concepts and case studies etc.

The resource materials that are suitable for support for BIM curriculum are often readily accessible on the internet and the videos are created and uploaded by various people including:

- the software providers of BIM
- professional bodies as part of Continuing Professional Development
- academics who have helped developed Models
- academics who have been involved in BIM research projects or who teach BIM
- companies and/or project team members of a particular project

Access to Models

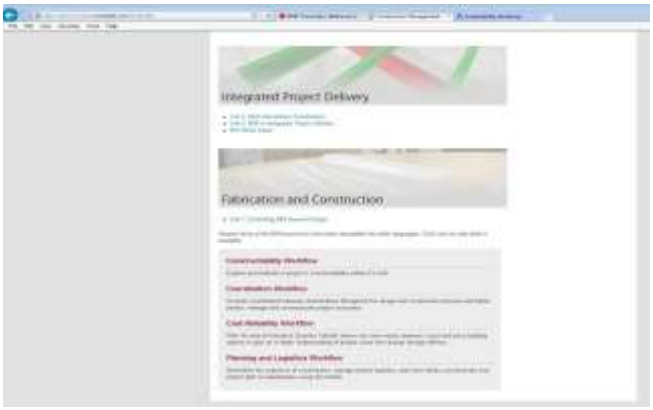
RMIT property services also commissioned a 3D model for its Swanston Academic Building (SAB) building as well as another building in Ho Chi Minh City, Vietnam. Selected members of staff in PCPM have access to this model although it is not a complete Federated Model (that is it doesn't have all the data on all objects in all disciplines and subdisciplines). Academic staff also have access to some industry employers who are willing to provide Models on a limited basis for teaching and/or research. However fundamentally the provision of Models is problematic because of ownership and intellectual property concerns. These matters can be dealt with but it is challenging. The Models often are not comprehensive and detailed enough for teaching purposes. The School would need to address this issue moving forward. (RMIT Navisworks Video.wmv SAB BIM video compiled by Nick Broadbent from BIMEDGE.)

Literature database

We have created a comprehensive database of literature in Endnote which will be made available to the School in our shared drive. The reference list is provided in this report.

Examples of Digital Education Technologies for BIM

The following are some examples of resource material readily available on the internet that staff can draw upon to support curriculum design and delivery. Additional materials are listed in the full report and this is still not a comprehensive list.

Software Supplier Resource Materials (Autodesk): Suite of Materials	
BIM Materials for Construction	
BIM Materials for Construction: Integrated Project Delivery Fabrication Planning and logistics	
Autodesk Transforming the BIM Process Introductory BIM video	
The Power of BIM BIM Value Proposition	

Outcome 9 Videos of staff and industry employers sharing their experiences

The original thinking prior to this project was that we would develop videos as resource materials to support the staff. However it became evident that there are numerous videos and online support materials available. The focus has now shifted to ensuring that the video material represents the local experiences to explain the BIM value proposition and the purpose of why BIM education is important. The videos are in the editing phase. The story boards are included in this report:

- Digital Global Connections and Smart Practices Digital Practices in Global Construction (Video 1)
- The Future Digital Construction Professional (Video 2)

3. Project outcomes and impacts

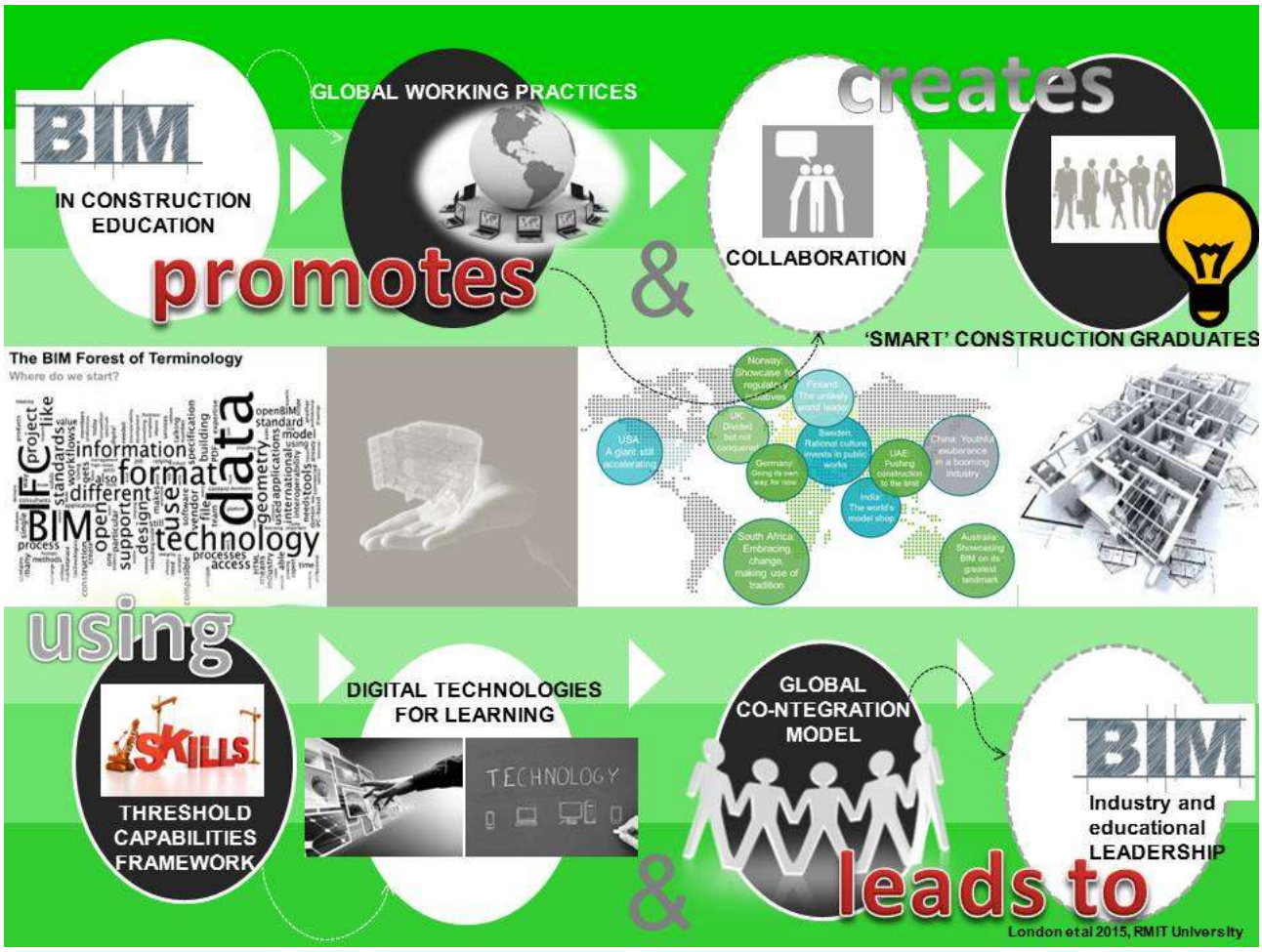
Original Intended Outcomes	Commentary
1. Create a map of undergraduate construction management programs in terms of learning outcomes, graduate profile, curriculum design, delivery modes, and global knowledge/skills vs local variances of the specific emerging important subject area : building information modelling and management.	Achieved although in a modified form. We mapped the majority of current teaching activities and experiences and insights of the academic staff in the various courses. We decided to explore the development of a Threshold Capability Framework as strategic holistic first step towards addressing curriculum redesign in this emerging area as it is premature to examine detailed course learning outcomes.
2. Identify and use the appropriate curriculum mapping tool(s) - for example C2010 Software for program level design and review and alignments between institutional-level intended learning outcomes (GAs), program outcomes, assessment types and requirements, learning support resources (Lawson et al, 2013)	Did not achieve. The extensive mapping envisaged was challenging as Current Course Accreditation documents of the programs were not readily accessible thus making it difficult to map course learning outcomes, curriculum design and delivery methods as envisaged by objective 1. We had anticipated that we would be able to use the current mapping of the programs across these main elements and simply overlay the mapping of the new subject area onto the existing curriculum mapping.
3. Develop with various inputs (industry leaders, literature, academic leaders, professional accrediting bodies) threshold concepts in relation to different learning categories	Achieved.
4. Develop a model within delivery teams for a holistic curriculum design and delivery approach that moves us towards the identified goal of the fully integrated virtual construction immersive environment student experience – ensuring that software and technologies for each course is identified and supported	Some progress towards this. The Phase 1 of identifying factors influencing curriculum redesign was analysed which will support a strategic approach change.
5. Evaluate international programs against the curriculum maps developed to ensure seamless offshore delivery	Some progress towards this. We evaluated the China program in the CAP however documentation was difficult to obtain and so this was challenging. We evaluated the leading international institution in undergraduate BIM as an exemplar case study.
6. Design and produce exemplar blended materials to support the curriculum design model taken and explain the approach so that existing and future students, staff, industry, professional accrediting bodies and institutional partners will understand our approach	Achieved. The project enabled a more nuanced approach to what materials were required and extended this objective.
7. Develop a Framework with Guiding Principles on curriculum design and delivery accounting for global foundational skills and knowledge as well as local context and variations	Achieved.
8. Disseminate outcomes to industry stakeholders	Achieved and Ongoing.

Global Passport through Co-integration of Construction Immersive Environments

Professor Kerry London, Associate Professor Tayyab Maqsood, Dr Peter Wong, Associate Professor Malik Khalfan and Nicola Willand.

School of Property, Construction and Project Management/Design and Social Context College

12 February 2015



Infographic Global Passport through Co-integration of Construction Immersive Environments

The following is a detailed report to support this LTIF Report.

Acknowledgements

The RMIT University Research Team gratefully acknowledge the following who have provided invaluable contributions and insights that have assisted the team in conducting the project, completing the research that underpins the project and developing recommendations and guiding principles for the School of Property, Construction and Project Management programs as they address this important area of industry capability of virtual construction management.

Person	Organisation
Ms Claudelle Taylor	General Manager NexusPoint Solutions
Mr Medy Hassan	National Construction Manager Hindmarsh Construction Australia
Mr Adam Siegel	General Manager, National Building & Business Improvement Metricon Homes
Dr Bilal Succar	Director, Change Agents AEC Pty Ltd
Mr Steve Appleby	BIM Practice Lead for AECOM for New Zealand and Australia
Son Nguyen	Senior Business Analyst / Estimating Systems, Nexus Point Solutions
Daniel Kalnins	BIM Manager, Nexus Point Solutions
Mauricio Vargas	Mauricio Vargas, Innovation Manager, Leighton Contractors Ltd.
Prof David Philp	Chair of the Chartered Institute of Building (CIOB) BIM working group
Dr Ron Webber	AIB National Vice President
Dan Collins	Graduate of 2011; Assistant Development Manager, Mirvac
Jing Yiing Chung	Graduate of 2013; Worked as a quantity surveyor until recently
Salman Azhar	Associate Professor and Graduate Program Chair, McWhorter School of Building Science, Auburn University
Prof Ron Wakefield	Head of School of Property, Construction and Project Management

Contents

1.1 Introduction

1.1.1 Aims, context and justification

The overarching aim of this project was to develop an academic educational framework for our undergraduate and postgraduate construction and project management programs to incorporate the delivery of Building Information Modelling and management in all courses at different levels. We shall confirm best practice models and shall redesign our programs aiming towards a fully integrated approach to teaching and learning of BIM knowledge, use and management. The Framework, with some modification, would have broad applicability to other disciplines. As we move towards streamlining our methods for developing diverse and multiple partnerships, this framework would help achieve co-integration of different approaches to curriculum design of core practices.

The specific objectives of this project were to

1 Create a map of undergraduate construction management programs in terms of learning outcomes, graduate profile, curriculum design, delivery modes, and global knowledge/skills vs local variances of the specific emerging important subject area : building information modelling and management;
2 Identify and use the appropriate curriculum mapping tool(s) - for example C2010 Software for program level design and review and alignments between institutional-level intended learning outcomes (GAs), program outcomes, assessment types and requirements, learning support resources (Lawson et al, 2013)
3 Develop with various inputs (industry leaders, literature, academic leaders, professional accrediting bodies) threshold concepts in relation to different learning categories – for example learning to become a BIM manager, thinking and understanding like a BIM manager and shaping the world as a BIM manager, (Baillie et al, 2012)
4 Develop a model within delivery teams for a holistic curriculum design and delivery approach that moves us towards the identified goal of the fully integrated virtual construction immersive environment student experience – ensuring that software and technologies for each course is identified and supported
5 Evaluate international programs against the curriculum maps developed to ensure seamless offshore delivery adopting the RMIT Equivalence and Comparability Framework and Process as a guide (.http://mams.rmit.edu.au/6kslnehdpsurz.pdf) and merging with the Principles developed in our discipline specific Localisation vs Universalism work
6 Design and produce exemplar blended materials to support the curriculum design model taken and explain the approach so that existing and future students, staff, industry, professional accrediting bodies and institutional partners will understand our approach
7 Develop a Framework with Guiding Principles on curriculum design and delivery accounting for global foundational skills and knowledge as well as local context and variations
8 Disseminate outcomes to industry stakeholders

An overarching question that guided the investigation to support this project is presented:

> *What would BIM curriculum to support an integrated virtual construction immersive environment student experience look like and how would we ensure co-integration with our international partner Universities?*

As we progressed through the study it became quite apparent that there are difficulties in introducing such changes as first envisaged. Developing curriculum change should not be conducted in a vacuum and understanding the environment and many of the factors that will influence implementation was one of the most important contributions that this Learning and Teaching project could make. We were faced with the following challenges during the execution of this project.

1. **Curriculum Mapping Availability:** Current Course Accreditation documents of the programs were not readily accessible thus making it difficult to map course learning outcomes, curriculum design and delivery methods as envisaged by objective 1. We had anticipated that we would be

able to use the current mapping of the programs across these main elements and simply overlay the mapping of the new subject area onto the existing curriculum mapping. If the documents were not readily available and the mapping not coherent then it is not possible to simply overlay a mapping of a new subject area.

2. **Lack of consistency in Program Mapping**: There is no uniform approach to curriculum mapping in the School as each program responds to the various Industry Professional Association requirements in relation to curriculum design and delivery. This then makes the task of drawing together a consistent approach impossible to achieve in the timeframe of this project and this was ultimately not the objective of this project. To address this problem we decided to focus on the Bachelor of Applied Science (Construction Management)(Honours) program as this is the largest program in the School and there are many common courses in the 1st year program with the other two programs (Bachelor of Applied Science (Property and Valuation) (Honours) and Bachelor of Applied Science (Project Management) (Honours). The construction management program is the program that will have the most influence in terms of developing work ready graduates in relation to the subject area of Building Information Modelling and Virtual Construction Delivery. The School also offers two postgraduate program (Masters of Project Management and Masters of Property). They have different environments in terms of this subject area. As a first step we decided to address the undergraduate curriculum design and delivery and then in the future address the postgraduate programs. That is not to diminish the importance of those two programs nor their achievements in this area already but just to clarify that with this subject area the construction management undergraduate program influence may be more pervasive.

Therefore the project is focussed on the following program: BH114 Bachelor of Applied Science (Construction Management) (Honours). There were other challenges identified that hinder the curriculum redesign and foreshadow streamlined implementation and these will be discussed in more detail in the various sections as well as the Recommendations sections of this report. In brief they include:

1. A coordinated approach that enhances existing initiatives and encourages a common vision using the Threshold Framework model as a guide
2. Development of deep engagement through a transition plan that accommodates both an organic evolutionary and planned structured approach to curriculum design and delivery
3. Continue to prepare graduates and ensure that they are resilient to the ever present changing conditions in this area in the local market where they are employed
4. University support for advanced information technologies in Learning and Teaching
5. Availability of appropriate Building Information Model and software application licenses to support teaching programs
6. Staff capability for delivery of teaching various aspects of Building Information Modelling
7. Exploration of co delivery opportunities and CPD environment and credit for prior learning opportunities
8. Pooling of resources

Project context and Justification

This project was concerned with the challenge of redesigning the learning and teaching of the programs in School of Property, Construction and Project Management to underpin program delivery through the **use** and **management** of the Building Information Model (BIM) within the context of a **virtual construction immersive environment** and ensuring that our **School delivery, international partnerships** and national and international **professional accreditations** are aligned. This novel approach is responding and leading to a global phenomenon, is industry based and is 'ahead of the game'. This approach will provide a unique student experience and enhance their ability to study and work anywhere in the world. The project brings together Building Information Modelling and curriculum design (or actually redesign) and therefore two important terms will be constantly referenced throughout the report.

1.1.2 Definitions: Building Information Models and Curriculum

The global phenomenon of the Building Information Model (BIM) is causing significant change to how we design, construction, deliver and manage our buildings. As the term Building Information Model will be used quite frequently in this report it is useful to explain this term. There have been various definitions of what a Building Information Model is and what constitutes the Modelling process and the following is presented as one of the more complete definitions of the concept of Building Information Modelling.

> *Building Information Modelling (BIM) is an information technology enabled approach that involves applying and maintaining an integral digital representation of all building information for different phases of the project lifecycle in the form of a data repository. The building information involved in the BIM approach can include both geometric data as well as non-geometric data. BIM is one of the important areas in current Virtual Reality (VR) research and is expected to envision efficient collaboration, improved data integrity, intelligent documentation, distributed access and retrieval of building data and high quality project outcomes through enhanced performance analysis, as well as multidisciplinary planning and coordination. (Gu and London, 2010).*

A layperson definition of what the term Building Information Model means was presented in the LTIF grant application and it is useful to provide this as well because it gives some ideas about the activities that would be undertaken as well as the content of what should be taught and thus begins to suggest how we might respond as educationalists who provide graduates who will operate in this new environment.

> *A Building Information Model is a virtual model of the proposed facility (building/asset) which has data and information on the physical properties (materials, components, systems) and the nonphysical properties (where to procure, when to maintain, relationships to other elements etc). This integrated repository ('Model') allows **analysis and simulations**, for eg change the columns from steel to concrete and we can immediately understand the difference in life cycle energy consumption, or the difference in total time to build or the cost differential. In its simplest form we develop one Model for a project but in its more complex form we integrate the Model to other information systems (online databases, companies historical records, government regulations etc) and work within a **virtual construction immersive environment**. (London, 2013).*

In the following Section 2 Theory: Part B BIM curriculum development and models we explain the context of how this new phenomenon has emerged and the promise it holds for the construction management discipline and all built environment disciplines. This is of course a very complex challenge for education providers and represents an industry wide and nationwide paradigm shift for all built environment stakeholders and also has the serious attention of nearly all countries involved in infrastructure design, construction, use and management. Thus the educational environment is a critical component of this entire system because our programs are so connected to the industry where our graduates are employed. A subtle question that underpins this piece of research is do we envisage leading or following industry in this paradigm shift or somehow do we have to develop a balance between the two?

The holistic and all pervasive change in what graduates may look like is being realised by many in industry and academia and government alike as BIM is being more and more viewed as not simply a technological innovation or tool but a way of thinking. As Nu and London (2010) prophetically suggested in 2010, BIM is an IT enabled *approach* not simply a technical system that is systemic and involves people, culture, processes, work practices and regulatory and policy frameworks.

Curriculum definition

There are various definitions of the term for curriculum and a few are presented here taken from Gosper and Ifenthaler (2014) who provide a succinct overview of the term in their Chapter Curriculum Design for the Twenty-First Century in the text, *Curriculum Models for the 21st Century: Using Learning Technologies in Higher Education*, which they edited.

According to Gosper and Ifenthaler (2014) Grundy (1987) '… as a theorist, frames curriculum as a way of organizing educational practices based on three rationales:

1. product where the focus is on reproducing knowledge for a defined outcome,
2. practice which emphasizes the development of understanding in order to make judgments and apply knowledge, and
3. praxis which focuses on critical reflection with outcomes determined by the community of learners" (Gundy as cited by Gosper and Ifenthaler, 2014 p1)

Print (1993), on the other hand, takes a more instrumental approach, offering three perspectives:

1. curriculum as experience, defined by a set of planned learning experiences encountered by students;
2. curriculum as intention, characterized by predetermined aims, goals, and
3. objectives describing what students should learn; and curriculum as a process, emphasizing personal growth and self-actualization through experiential learning

In the absence of a universal definition of the term curriculum (Gosper & Ifenthaler, 2014), this review has adopted the definition of the 'total curriculum' by Kelly to denote the overarching principles of an educational experience. Curriculum thus refers to the institutional structure of programs, courses and syllabi and includes the knowledge content and course subjects, as well as pedagogic approaches to teaching and learning, educational activities and assessment (Kelly, 2009).

1.1.3 RMIT University, College and School priorities

We now shift focus a little and turn to the educational environment that this project sought to address. This project is in strict alignment with RMIT strategic plan with Goal 1: Global in attitude, action and presence, offering our students a global passport to learning and work. It matches very well with Priority 1, Priority 2, Priority 3 and Priority 4;

> *Priority 1: Develop an integrated global strategy to guide development of our global presence*
>
> *Priority 2: Grow and diversify RMITs network of teaching, research and industry partnerships in selected city locations across the world. These partnerships will support our high impact areas of education and research by increasing the quality and quantity of offshore education*
>
> *Priority 3: Define and deliver an RMIT student experience that is characterised by its global engagement, international mobility and cross cultural opportunities.*
>
> *Priority 4: Support global engagement by all RMIT staff by initiating development and improvements to internationalise academic programs*

Coupled with this the project focuses on the following 2014 LTIF priority:

> *designing or redesigning sustainable programs for onshore and offshore delivery, including flexible delivery*

The College and the School work plans have objectives to increase and improve international offshore delivery and this project seeks to achieve this. The 2013 Program Annual Review (PARS) for the School of Property, Construction and Project Management identified 3 Priority Actions for the School. One of those three priorities is International Development and growing our programs offshore. The School has a strong presence in Singapore and Hong Kong. The most recent offshore agreement is the CAP program with China University of Mining and Technology. This agreement would allow 90 Chinese undergraduate students, every year from 2015 to come to RMIT and complete their last 2 years of construction management studies in the School at the city campus in Melbourne.

The School of Property, Construction and Project Management is seeking to increase offshore delivery in Europe and China. The School is focussed on offshore delivery of our programs. We have initiated offshore delivery of our undergraduate and postgraduate programs in various locations including; China, Vietnam, Hong Kong and Singapore. We are seeking to increase our offshore delivery in Europe as well.

1.1.4 Construction management program graduates

Program purpose

The following is extracted from the 2014 Program Guide.

---

*The Bachelor of Applied Science (Construction Management) (Honours) will develop the **theoretical knowledge and technical skills to enable you to work effectively as a construction management professional**. In doing so, you will develop the skills and knowledge required to meet the industry need for specialisation.*

*This program has been structured to develop your knowledge of the construction process in the wider social, environmental, regulatory, technical and economic contexts. The courses in this program have been designed to enable you to **critically engage with contemporary construction management theory, situating your learning in the wider industry context**. The program is designed to enable you to undertake project based learning to equip you with the skills required by the construction industry.*

*Through your learning in this program you will critically evaluate and apply construction management concepts and methodologies including building your knowledge in key areas including building design, building services, construction methods and processes, procurement and supply chains, sustainability, economics and resource management. In doing so, you will develop **your ability to formulate and justify evidenced based solutions to industry problems.***

*Your developed specialised skills will be underpinned by your research and investigative skills, and your **ability to critically assess the increasingly complex construction management industry and market**. As a critical thinker, you will be able to apply your well-developed analytical skills to critically review, interpret and synthesise construction management theory and knowledge. Your developed **discipline specific and interdisciplinary knowledge of construction management practice and principles will be applicable to a range of organisational contexts and construction industry settings**, and will enable you to **contribute effectively to the management of the construction process.***

In the final year, you will complete a project-based capstone course BUIL 1262 Construction Planning and Design 3 in which you will synthesise and integrate your knowledge and skills, connect theory and practice, as well as demonstrate your holistic understanding of the program's learning outcomes.

Upon successful completion of this program you will have developed the specialised skills and knowledge to enable you to work as a construction management specialist in a range of roles including as a: chartered builder, chartered quantity surveyor and a chartered building surveyor.

You will develop the skills required to apply your theoretical and practice based knowledge to meet the needs of a range of stakeholders within the construction industry including contractors, developers and consultants. Graduates of this program will be equipped with a sound knowledge of construction management strategies, production factors and the industrial environment within local and global contexts and will be able to independently analyse industry trends, current and emerging. You will be adept in working independently and collaboratively, applying your well developed cognitive and technical skills to address and respond to industry issues, scenarios, trends and problems. Successful completion of this program provides a pathway into a Masters. Upon successful completion of this program you may also be eligible to undertake further studies in related programs at RMIT University.

1.1.5 Drivers to develop BIM curriculum

The most recent relevant international construction industry survey is the 2014 McGraw Hill Construction SmartMarket Report, "The Business Value of BIM for Construction in Global markets: How contractors around the world are driving innovation with Building Information Modelling". This survey provides analytics on the adoption of BIM in ten countries around the world including US, UK, Canada, France, Germany, Australia, Brazil, Japan, New Zealand and Korea. Clearly the message was that adoption of BIM is an important part of the future of the construction industries in these countries. According to the results of the survey although BIM Implementation has been underway in US, UK, Canada, France, Germany, '…the markets that have begun adopting BIM more recently, such as Australia, Brazil, Korea, Japan and New Zealand are showing tremendous momentum and are outperforming the more established regions in several key categories of research such as ROI, commitment to investment, offering innovative new services and expanding the use of BIM to non-building projects such as mining and infrastructure'. Australia's movement in adopting BIM shall be explored through the eyes of some of our graduates, industry professional association representatives and employers that we interviewed and described in the results section of this report. Interestingly our findings also support the emergence of the expanded use of BIM to nonbuilding projects in the mining and infrastructure sectors – and various interviewees raised the issue of renaming BIM to a more generic term.

If according to Jones and Bernstein (2014);

'Change is sweeping the globe. Project Teams are benefitting from faster communications, smaller, more powerful and mobile computers, robust digital modelling tools and a transformative shift towards integrated project delivery processes, all of which are generating positive outcomes, efficiencies and benefits unimaginable just a few years ago'

…then where does that leave us with the education of the construction management professional of the future given the purpose of our program?

If our program is to ensure that our graduates will have the theoretical knowledge and technical skills to enable them to work effectively as a construction management professional and to critically engage with contemporary construction management theory, situating their learning in the wider industry context, **we need to establish some form of commitment to Building Information Modelling and take leadership in Australia.**

The construction industry has often been viewed in the past as quite creative and technologically advanced and yet also on the other extreme as quite slow to innovate and adopt. It is a confused industry both being quite traditional and resistant to change in some quarters and then in other areas willing to take risks, and design and construct beautiful and elegant technical solutions that are quite novel drawing upon incredible problem solving abilities and leadership. The profile of our graduates needs to change from a construction professional who will be managing a craft based industry to the 'smart' construction professional who is focussed on communications, data and information modelling, analysis and management.

Governments in many countries have encouraged construction to transform itself in a range of ways

1. into a low-carbon sector
2. to increase productivity and
3. adopt more innovations (BBF 2009, USEPA 2009).

It has been widely acknowledged that education and training is necessary for such transformations. As discussed previously there is a need to rethink the type of professional with a much greater emphasis on 'smart thinking' and analysis capabilities and decision making. Key to this change is a transformation of teaching and learning of the use of Building Information Models to accommodate the emerging international trend of advanced information technology adoption in the industry. To maintain international standards it is timely to reappraise our program.

At RMIT we have the opportunity to lead in this because of our focus on 'urban' and 'technology' and also because we are well placed with having access to Building Information Models. One of the difficulties teaching institutions have had is having Models to use as teaching materials because of the ownership, intellectual property and rights issues or because the supporting industry simply were not advanced enough to have advanced Models to share. We are well placed to have a suite of Models to use in our School because as a leading 'client' RMIT is developing Models of all their buildings both here in Melbourne and in Vietnam. The School is working closely with RMIT Property Service and there may be a suite of Models available in the future. No client/building owner in Australia has embarked upon this and very few teaching institutions have this capacity or access. Through the Vietnam campus Models we are also experimenting with cloud technology and so our School in the future could be enabled to experiment and participate in virtual teaching studios for the building disciplines – a first in the world.

1.1.6 Impact on curriculum design and delivery

Conventional approaches to curriculum design and traditional delivery modes of lectures and tutorials may no longer be suitable for nurturing future construction professionals who should excel in data and information modelling, analysis and management to increase project productivity. Until now, a deeper understanding of how curriculum design can match with the future demands and expectations is still lacking.

The mapping and the curriculum design models to be developed through this project will enable the university to recognise the strengths and weaknesses of the current learning and teaching strategies being adopted in both on-shore and off-shore programs offered by the School of PCPM. This will provide insight in how various software tools and techniques for advanced data and information modelling and management across all program content could be applied in various onshore and offshore learning and teaching environments. In 2013, the School started the delivery of construction management program in partnership with a local partner in Hong Kong. The School has also signed an agreement with China University of Mining and Technology (CUMT) in China to accommodate 90 undergraduate students from 2015 annually. After these successful ventures, the School is in prime position to investigate the delivery its others programs in range of international locations.

There are numerous ways that we could approach curriculum design in response to this global industry phenomenon. We could take a minimalist approach and teach about Models or we could reshape our approach and be a leader nationally and internationally in the use of Models as the core integrating platform that underpins all courses. Thus all courses in a construction management program could relate to BIM teaching because all industry work practices have either changed, are changing or will change to be focussed on BIM use and management. In some parts of the

construction industry the Model will become the central focus of project delivery in the future however it is important to remember that some parts of the construction sector are slow to adopt change and so our graduates may find themselves in an innovator or early adopter company or alternatively in a late adopter or laggard company. So our intention is to consider what the implications are for program design and delivery if we were to replicate and enhance industry practice and use the Model as the integrating focus in program delivery but still ensure that graduates are well equipped for those places that have not implemented BIM.

Professor London, in collaboration with an industry partner Ms Claudelle Taylor from Leighton Holdings Group, supervised some undergraduate research students in 2012 who analysed several undergraduate teaching programs and their uptake. The programs were both local and international. The students (with guidance) identified that there are three levels to 'BIM' curriculum design for the management professional programs in the built environment (i.e. Construction, Project Management and Property);

- Level 1: teach BIM in an adhoc way by making it part of 1-2 courses
- Level 2: teach BIM in a stream of courses in each year of delivery
- Level 3: teach BIM in all courses and immerse students in the virtual environment (i.e. virtual construction immersive environment).

Currently we are at level 1 and there is no University that is at level 3; with only one leading institution (notably one or our research partners in Europe, University of Salford) aspiring to implement a staged approach of total immersion by 2015 in a postgraduate program. We shall discuss this in more detail in Section 6 Results and Discussion.

1.1.7 Internationalisation and partnerships

Added to this complexity of establishing a clear direction for our programs in the Schools we need to co-integrate with our current and future partners as we progress our offshore delivery plans. In this project we would like to:

- Investigate, analyse, develop and initiate our BIM curriculum approach

- Develop discipline specific maps to aid decision making when mapping curriculum against partner programs for offshore delivery

We have found that a significant challenge is mapping pedagogical approaches to curriculum design within our own teams and also our partner offshore teams. Internationalisation of curriculum is a complex matter and for a more complete discussion on the challenges refer to our publication: 'Localisation vs Universalism of professional Practice in curriculum internationalisation', K.London, P.Zhang, J.Siva, T.Maqsood, Australian University Building Education Association, Auckland, 2013. *(Attached in Appendix). and also Final Report for Vietnam Development Fund project 2013.*

We would like to develop a methodology to analyse, assess and evaluate the inter-relationship between different curriculum design and delivery models for seamless offshore delivery of the use of the BIM in an immersive construction environment to ensure that our students do have the global passport to seamlessly study and/or work in other locations in the world. We would attempt to build our School methodology and ensure that we can respond to different strategies that our current and/or future partners might take in this unique discipline specific context.

The difficulty we anticipate in offshore delivery is maintaining international standards when there are differences in approaches to curriculum design and content related to two factors;

- local industry context nuances vs universal principles of knowledge and skills (models creation and use may be different although there it is noted that there is a 'universal' language) and;
- the decision to embed this subject area in all courses as it relates to all content and work practices vs developing a specific subject stream vs the fully integrated approach.

Therefore, we need to develop a clear method for us to co-integrate across diverse approaches and contexts. The international accrediting bodies always provide a guide in this respect because in some countries (not all) this is the real barometer that the industry uses to evaluate programs and graduates and so our interviews which are reported on later on in the results section provide interesting insights.

1.2 Outcome 1: Resources to guide the School in curriculum redesign in BIM Education

Increasing adoption of BIM in the construction industry in developed countries is supposed to signal a "paradigm shift" (Barison & Santos, 2010; Casey, 2008) and that BIM will eventually be regarded as the lingua franca (Casey 2008). Interestingly formal BIM accreditation criteria appears to be still missing and it has been the BIM triggered transformation of the architecture, engineering and construction management (AEC) sector that has been driving a change in curricula amongst the AEC schools globally (Hyatt 2011). Hence, curriculum guides have been published that included Building Information Modelling (BIM) and the teaching of BIM has becoming increasingly popular in higher education (Joannides, Olbina & Issa, 2012; Wu & Issa, 2014). It was suggested that construction courses should stress BIM as a methodological rather than mere technological tool. While outlines for course content had been published, research into the effectiveness of BIM was still rare. This literature review is to provide an up to date overview of BIM education with a particular focus on the approaches to curriculum design. We do not explore the difficulties of implementation in detail nor the argument or the merit of including BIM.

1.2.1 Background

In accordance with Outcomes Based Education (OBE), BIM education at undergraduate level should meet the needs of students and industry. There seems to be the realisation that academic institutions had to incorporate BIM to prepare graduates for the novel reality of managing constructions projects in the digital age (Wong, Wong & Nadeem 2011) and that BIM education was likely to assist students in their career paths (Woo 2007).

Although universally accepted literature on curriculum guidelines for undergraduate degree programs in BIM for construction management programs are still not prevalent. However, BIM is increasingly appearing in construction management courses in the US, UK, Scandinavia, Singapore, Hong Kong and Australia (Wong, Wong & Nadeem 2011). A survey in 2009 found that only about a third of undergraduate construction management programs in the US had required courses with BIM components (Becerik-Gerber, Gerber & Ku 2011). Four years later, a survey of American tertiary education institutions affiliated with the Associated Schools of Construction (ASC) revealed that over half of the schools claimed to offer BIM dedicated courses or to have included BIM content into their existing, conventional courses (Joannides, Olbina & Issa, 2012; Wu & Issa, 2014). Half of the surveyed construction schools used BIM for the modelling of scheduling and estimating and only a third for 3D modelling in their undergraduate courses (Joannides, Olbina & Issa, 2012). Almost two thirds of the twenty-four respondent construction schools were planning to fully integrate BIM into their curriculum (Joannides, Olbina & Issa, 2012). The number of respondents in the survey was 43.

Nonetheless, a universal approach or national framework for teaching BIM in AEC programs in the US seemed to be missing (Sacks & Pikas 2013). The integration of BIM into curricula was supported by the BIM Forum website (BIMForum 2014) and annual BIM Academic Education Symposium (National Institute of Building Sciences 2014), which served as a platform for the exchange amongst academics and industry. Pooled efforts to integrate BIM into curricula were found in the UK, New Zealand and Australia and these are now considered.

1.2.2 BIM curriculum development: UK, US, Australia, New Zealand and Israel

Initiatives to develop common frameworks for BIM education in the tertiary AEC disciplines in the UK, New Zealand and Australia have already produced guidelines for the incorporation of BIM into higher education courses (BIM Academic Forum UK, 2013; Miller et al., 2013; Mills et al., 2013). In the US and in Israel, BIM curriculum development is located in the domain of each institution. Institutions aiming for a meaningful BIM embedded curriculum have typically adopted a strategic approach, in which learning outcomes were defined and adapted to levels 1-6 of Blooms taxonomy of cognitive domain.

UK

In the UK the BIM Academic Forum (BAF), formed by leading academics of UK and Irish universities has initiated the development of a national roadmap for the integration of BIM into the curricula of higher education qualifications (BIM Academic Forum UK 2013). The framework creation was driven by the government mandate of BIM usage on all public works projects by 2016 being channelled through a supply chain which is BIM 'level 2' compliant; 'level 2' is defined as file-based collaboration and library management. Aligned to this it was recognised that there was a need to work with the professional institutions in addressing new requirements in the accreditation of courses. The BAF published Preliminary Learning Outcomes in July 2012, which consisted of 49 learning outcomes categorised into three areas of need with sub-categories:

1. Strategic - overview, strategic considerations
2. Management - acquiring internal resources, developing organisational business plan, managing external requirements, managing people, managing process, managing technical infrastructure
3. Technical - (no sub-categories) (BIM Task Group 2012).

All learning outcomes stated 'understand' as the required level of depth, which corresponds to Level 2 in Bloom's Taxonomy. The BAF (BIM Academic Forum, 2013 p 10) also provided suggestions of how BIM knowledge and understanding, practical skills and transferable skills could be introduced progressively into Year 1 (introductions), Year 2 (concepts, collaborative working) and Year 3 (knowledge of multi-disciplinary, legal, data management) of a Bachelor Degree. The following is the summary of the Level 4, 5 and 6 learning outcomes which corresponds to 1st, 2nd and 3rd years in the UK undergraduate degree.

Summary

Level 4 (year one of undergraduate study): essentially, the key learning outcomes at this stage are to provide the context and background to the industry, and why the need for significant productivity improvements exists, set against the historical and traditional working arrangements which have prevailed. This will cover an appreciation of how the industry works, the key roles and disciplines involved in delivering projects and identify the nature and role of the various stakeholders. It should also include an introduction to the way in which information is prepared, shared and issued and also to the technologies being employed to support BIM and promote collaborative working.

Level 5 (year two): outcomes here aim to develop the knowledge and understanding of the role of BIM as a business driver for collaborative working within an integrated supply chain, considering the roles and responsibilities of each within a BIM approach. Students should be able to investigate and articulate the value proposition for BIM from the perspective of each party and consider the impact of BIM in terms of life cycle and whole life cost on projects.

Level 6 (year three and potentially after year out in industry): at this level there should be a greater focus on building competence and knowledge around the people, systems and process which are required for BIM to be delivered successfully on projects. This should include the ability to fully articulate the benefits of BIM. There should be awareness and appreciation of the cultural and organisational impacts of change necessary for the adoption of BIM both people issues and practical issues; awareness required of the practical measures necessary for BIM implementation including understanding of available technologies, means for exchanging data, standards and protocols;

> *and appreciation of new ways of working in groups/projects—integrated project team work and collaborative working environments to support BIM delivery. (BIM Academic Forum, 2013 p 11)*

The guide included suggestions of BIM topics for postgraduate courses.

The Guide also discussed a BIM Teaching Impact Matrix which described four levels of application of BIM teaching including:

1. **Absent:** BIM is a nice research area but should not affect what and how we teach. Our students do not need to know about BIM.
2. Aware: BIM is a nice research area but should not affect how we teach. Our students should be aware of BIM and how it might impact their future.
3. Infused: Students should understand how BIM will affect their future and have chance to learn BIM in a discipline & multi-disciplinary context.
4. Embedded: BIM is so important it should become the 'vehicle' for our students' learning experience. Teaching should be enabled by the BIM model.

Each of these levels has implications for curriculum, staffing and infrastructure and these were briefly noted.

Australia

In Australia, the CodeBIM project, 'Collaborative building design education using Building Information Modelling (CodeBIM)' (Mills et al., 2013) was a Learning and Teaching research project funded by the Australian Government Office for Learning and Teaching (OLT). The aim of the project was to focus on collaborative building design between architecture, engineering and construction disciplines and to:

> *a. Develop an understanding of the awareness and teaching of collaborative AEC education in Australian universities, and the current extent of the use of BIM within them; and*
>
> *b. Incorporate collaborative design in architecture, building and engineering programs in Australia, utilising BIM tools. (Mills et al, 2013, p5)*

This was an ambitious project that sought to bring together the three disciplines using BIM. The authors even acknowledge that 'The development and implementation of curricula that will allow truly inter-disciplinary building design courses, through the use of BIM technologies, in a way that will change the way AEC education is traditionally delivered, is an ambitious goal.". It is ambitious because collaborative design integrating the three disciplines rarely exists currently without the added complexity of BIM. BIM is taught across the disciplines in varying levels in Universities and students have different levels of collaborative design skills and capabilities coupled with different levels of BIM competencies. The study resoundingly confirmed this lack of cross collaboration.

> *Most notably, there was no evidence that any universities are fully utilising or developing educational collaboration between the AEC disciplines using BIM at the time of the audit.*

However the project did produce a framework to approach collaborative building design teaching using BIM. CodeBIM developed the IMAC framework, an acronym for Illustration, Manipulation, Application and Collaboration, based on the Construct IT benchmarking tool for information technology adoption in construction companies. Resources were developed to assist academics in mapping current levels of collaborative design in Universities across the disciplines, flowchart for implementation, description of the phases of the IMAC framework and target charts for each

discipline. The material is very high level at this stage. The IMAC components were mapped to Blooms Revised Taxonomy stages, however no guidance was provided on the sequence of implementation of the various modes of learning and little detail on learning outcomes. The courses that were developed as part of the CodeBIM project and have been piloted at the University of South Australia did not always equate deeper level of knowledge with advancement of years of education. For example, a BIM illustration module, which would be classified as a lower level in Bloom's taxonomy, was part of a Year 4 course (Mills et al., 2013).

Based on a document analysis of the general graduate criteria for the leading accreditation bodies for Construction Management degree programs in Australia, namely the Australian Institute of Building (AIB), Australian Institute of Quantity Surveyors (AIQS), Australian Institute of Building Surveyors (AIBS), Royal Institute of Chartered Surveyors (RICS) and the Chartered Institute of Building (CIOB), CodeBIM suggested targets for BIM proficiency for Construction Management degree programs. According to the chart, construction management graduates, in keeping with their potentially pivotal role in managing multi-disciplinary teams, should be highly efficient in the use of BIM as a collaborative tool (CodeBIM, 2014).

The project has taken BIM from the perspective of BIM as a collaborative building design tool however that limits the usefulness of the tool to one phase of a building's lifecycle. The two other significant phases are construction and in-use management. As highlighted by London and Taylor in 2009 in a series of national seminars for the CIOB this is a fairly common dilemma in the Australian construction industry. The championing of BIM within the construction management and the facilities management disciplines is still in need of attention. The value proposition of BIM to construction management is emerging as indicated by the McGraw Hill survey and hence we need to develop depth in our curriculum that addresses the core activities that are associated with the construction management profession. It is not only a collaborative design tool it is also a collaborative design management and construction management tool and these are core graduate attributes of the construction management professional graduate.

New **Zealand**

In New Zealand the drive to incorporate BIM into academic curricula was driven by educators, led by the University of Auckland and industry. Miller (Miller et al., 2013) proposed a framework that embraced vocational training, university degree programs and research programs. The framework suggested 18 learning outcomes according to the level of the educational program. The five learning goals applicable to AEC bachelor degree programs were:

> *Graduates have a sound understanding of underpinning key principles of BIM;*
>
> *Understanding of 3D modeling techniques and ability to manipulate 3D models;*
>
> *Appreciation of the wide range of benefits derived from BIM*
>
> *Able to use a variety of BIM software;*
>
> *Able to use BIM effectively in a range of design and /or construction scenarios" (Miller et al. 2013 p 614)*

Israel

The Technion-Israel Institute of Technology, Haifa, Israel, systematically developed, and was in the process of implementing BIM into their curriculum of the Construction Engineering and Management program (Pikas, Sacks & Hazzan, 2013; Sacks & Pikas, 2013). Based on a multi-method consultation with practitioners and academics that included discussions on a professional social network site, a workshop with leading international practitioners, a survey of practitioners, and the analysis of BIM related job descriptions, the university developed guidelines for the adoption of BIM into the program

(Sacks & Pikas, 2013). Thirty-nine (39) topics of expertise or learning outcomes were identified and categorised into the three knowledge areas of:

1. Processes - general knowledge area (e.g. management. and contracting procedures, constructability review, legal aspects),
2. Technology - BIM skills and technology (e.g. BIM operating skills, modelling, data storage and sharing) and
3. Applications (BIM functionality/ application) (e.g. create renderings, perform energy/ structural analysis/ automated quantity take-off and cost estimation, 4D visualisations of construction schedules).

These learning outcomes were graded according to Bloom's taxonomy classification levels 1 to 6. According to the framework, the recommended levels of achievement for the first degree would reach Level 3 (Application). A Masters degree would require a proficiency of Level 4 (Analysis) in most topics. The framework suggested that Levels 5 (Synthesis) and 6 (Evaluation) required experience in the work place (Sacks & Pikas, 2013). All knowledge areas were located in the cognitive domain. The framework indicates that construction managers had to possess a high level of achievement of BIM as a communication and feedback tool, in model-progression specification and level-of-detail concepts, design coordination, management of information flows, interoperability and the generation and the evaluation of construction plan alternatives. Hence BIM education in construction management degrees had to place the emphasis on managing information, information flows and construction competence (Sacks & Pikas, 2013).

USA

In the absence of a national framework in the US, BIM inclusive curriculum development was specific to each institution. Nonetheless, individual academic institutions in the US were moving quickly to adapt their curricula to the emergence of BIM (Sabongi 2009; Wu & Issa 2013).

A survey of 101 AEC programs in the USA (Becerik-Gerber, Gerber & Ku 2011) found that the incorporation of BIM had started predominantly between 2006 and 2009. The process was led by architectural schools who at the time of the survey offered more BIM components than construction management programs. In general, all disciplines were planning an expansion of the BIM aspects into the curricula (Becerik-Gerber, Gerber & Ku 2011).

Wu & Issa (2013) found that BIM was predominantly in undergraduates degrees; a quarter of the responding institutions was offering extra-curriculum BIM workshops and events. The main emphasis of the courses was on training in software application. On average, institutions cautiously assessed their own level of BIM integration as 'moderate'.

One of the early adopters of BIM education was Auburn University which was also highlighted by the Australian researchers in their international benchmarking within the CODEBIM project.

1.2.3 BIM integration curriculum models

Various reviews of the current state of BIM incorporation into curricula have been conducted (Barison, & Santos, 2010; Becerik-Gerber, Gerber & Ku 2011; Lee & Hollar, 2013; Miller et al., 2013; Sabongi 2009; Sacks & Pikas, 2013; Wong, Wong & Nadeem 2011; Wu & Issa 2013) and various classifications have been proposed. The following classification was based on the scenario in which BIM could develop its full potential, which was the holistic application of BIM as a lingua franca in a collaborative context. The extent of BIM in the curriculum is generally a reflection of the institution's and staff's attitude to BIM as well as available resources, (BIM Academic Forum UK, 2013).

The attitudes to and extent of introducing BIM teaching into current curricula ranged from the mere acknowledgement of the presence of BIM to the embracement of BIM into all elements of the program and across disciplines. Research into the current state of BIM curricula, which formed the basis of the following categorisation, addressed mainly the US context (Barison & Santos, 2010). Models of curriculum design were categorised as either detached, aware, infused, combined and embedded with or without a cross-disciplinary component. In contrast to the models for integrating sustainability education into university curricula, the review of the literature did not find any examples in which BIM was offered as a specialisation option or in which a second BIM Construction Management course was offered as a separate program.

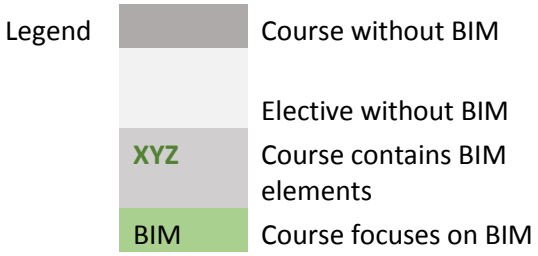


Figure 1 Legend for curriculum models

Detached category

The detached attitude of some institutions promoted the autodidactic approach, in which BIM was self-taught without any formal instructions by the institution. Self-taught BIM components were used in combination with program integrated BIM courses or as standalone courses (refer to Figure 2.2).

A survey of over 100 USA AEC schools in August and September 2009 revealed that almost a fifth of architectural schools expected their students to acquire BIM knowledge and skills by themselves, independently of the schooled program. According to the survey, this approach was not followed in any of the construction management schools (Becerik-Gerber, Gerber & Ku 2011). However, Taylor (Taylor, Liu & Hein 2008) reported such an approach for a special thesis for remote students enrolled at Auburn University. Despite having achieved an impressive level of competence, the students expressed dissatisfaction with this delivery of teaching. Staff agreed that the complexity of BIM demanded a different learning method (Taylor, Liu & Hein 2008). Exposure to BIM could also be achieved through student internships (Barison & Santos, 2010).

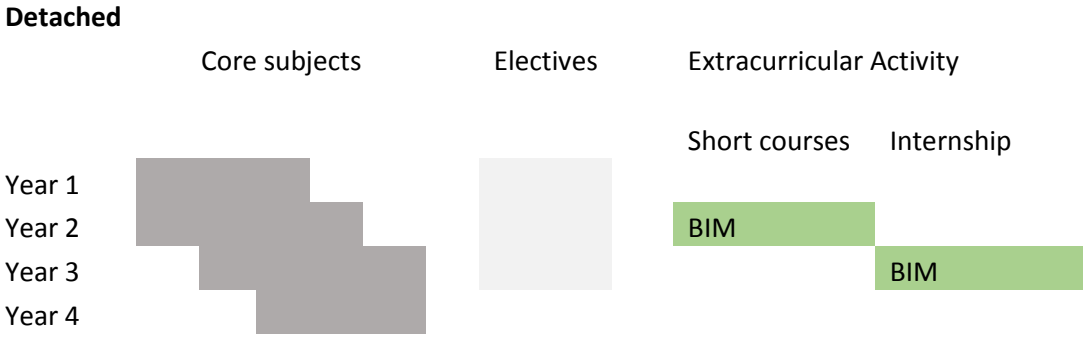


Figure 2 Curriculum model – Detached

Aware category

Universities that were aware of the need approached the introduction of BIM by creating discipline-internal single courses approach (Barison & Santos, 2010; Taylor et al., 2008). BIM was taught as part of an existing information technology course, e.g. replacement of 2D CAD with 3D BIM (Taylor et al., 2008). Alternatively, new dedicated BIM stand-alone courses were created (refer to Figure 2.3). A survey of over 100 AEC schools in the USA revealed that in 2009 two thirds of construction management programs offered BIM dedicated undergraduate courses (Becerik-Gerber, Gerber & Ku 2011). Lee et al (2012) listed various examples of programs that were a reflection of the 'aware' categorisation.

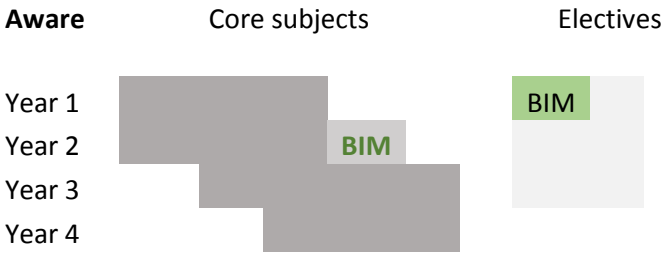


Figure 3 Curriculum model – Aware.

Infused category

Infusion of BIM at referred to the adaptation of the existing construction program curriculum to incorporate BIM (refer to Figure 2.4). This integrated approach was considered to better reflect the demands of the construction industry (Hyatt, 2011; Wong, Wong & Nadeem, 2011). A survey showed that fusing BIM into the existing program was a common approach among construction management schools in the USA (Becerik-Gerber, Gerber & Ku, 2011). The Australian CodeBIM report recommended this approach (Mills, 2013). The University of South Australia restructured their civil engineering curriculum to incorporate more BIM topics and trialled some revised courses offerings (Mills, 2013). Miller also favoured the adoption of BIM components into existing courses for undergraduate degrees in New Zealand (Miller et al., 2013).

Infusion of BIM into conventional classes was considered the "most practical approach" to integrate BIM into existing conventional programs (Lee & Hollar, 2013). Lee (Lee & Dossick, 2012) listed examples in courses covering mechanical, electrical, plumbing and structural engineering, estimating, scheduling and project management and Taylor, Liu & Hein (2008) describe further examples. For example, in 2008, Auburn University introduced a final year capstone project based on BIM (Taylor, Liu & Hein, 2008). The BIM option was voluntary and only available after special consideration. The students who had little prior knowledge of the range of BIM functions prior suggested that a BIM capstone project would require a keen interest in information technology (Azhar, Sattineni & Hein, 2010).

Infused/adapted/ intrinsic

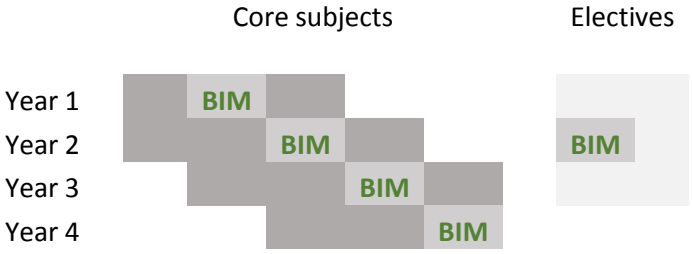


Figure 4 Curriculum model- Infused.

Combined category

The combined strategy to introducing BIM into the curriculum referred to a mixture of stand-alone BIM dedicated courses and courses in which BIM was infused into the conventional syllabus (refer to Figure 2.5) **S**hen (Shen et al., 2012) stated that the common approach was to teach the students the basic skills of BIM in dedicated BIM classes. In subsequent years BIM components were then integrated into courses with various overarching learning outcomes. This combination was also recommended by Sacks (Sacks & Pikas, 2013). Miller et al. (2013) believed that an "incremental, organic integration into existing Bachelor level degrees probably" would be a "more acceptable and sustainable approach". For the New Zealand context, Miller proposed a combined approach of BIM electives during the undergraduate years and BIM integrated into courses of the existing curriculum for honours students (Miller et al., 2013).

Examples of this approach found in the literature were from Auburn University and Southern Illinois University. Auburn University offered a week long short course on BIM with an introductory course the following semester (Taylor, Liu & Hein, 2008). The integration of BIM into the final year capstone project was voluntary (Azhar, Sattineni & Hein, 2010). Gordon (Gordon, Azambuja & Werner, 2009) described a sequential pilot application of BIM across the four years of the curriculum of the Southern Illinois University (Gordon, Azambuja & Werner, 2009). The 'educational objectives' indicated a focus on "understanding" of BIM functionalities (cf. Table 1, page 22), i.e. achievement of Level 2 of Bloom's taxonomy.

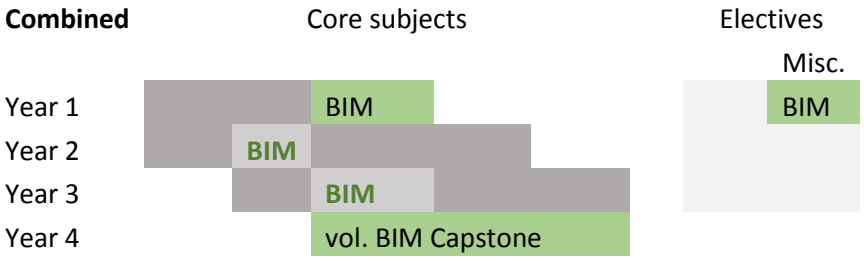


Figure 5 Curriculum model – Combined

Stream-lined category

Casey (2008) reported on a stream-lined adoption of BIM in a civil engineering curriculum that involved the sequential and progressive teaching of BIM over several years at the George Mason University. The transportation design curriculum adopted the principles of "mastery and immersions" (Casey, 2008; pp. S4J-6) in which students were working on the same project in every of the three years, but building on the skills of the previous year having to solve increasingly complex problems. Year 1 aimed for the illustration and manipulation, Year 2 for application and in Year 3, the capstone design course, the synthesis of the acquired BIM knowledge was required. The university's eventual goal was to introduce cross-discipline collaboration during the final year (Casey, 2008). Figure 2.6 is indicative of a stream-lined approach.

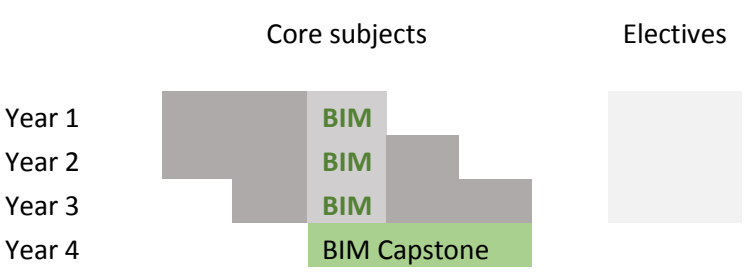


Figure 6 Curriculum model – Stream-lined

Embedded category

Embedding BIM into a program curriculum requires universal teaching based on BIM in all courses (refer to Figure 2.7), BIM was seen as "the 'vehicle for student learning" (BIM Academic Forum UK, 2013). Sacks (2013) envisages an approach in which BIM topics and tools were used throughout the curriculum "in manageable chunks to create rigorous and stimulating learning". The integration of BIM into a variety of courses was seen to reinforce BIM as a "common language" between stakeholders (Pikas, Sacks & Hazzan, 2013). Documented examples of embedded curricula were still rare.

The first account of the strategic and systematic implementation of a BIM-Integrated curriculum was provided by Pikas (Pikas, Sacks & Hazzan, 2013). The Technion-Israel Institute of Technology, Haifa, Israel, developed guidelines for the adoption of BIM into the curriculum of the Construction Engineering and Management program, based on the 39 topics of expertise/ learning goals outcomes established by Sacks (Sacks & Pikas, 2013). In an 'experiment' to trial the implementation, four courses that represented both design and management and covered all four years of education were selected. All of these were existing courses, three of which were already infused with BIM content. One course, the Advanced BIM course, was created new. Brief course descriptions were provided.

Lee et al. (2013) have published a guideline for the integration of BIM in Construction Engineering and Management Education based on a survey of BIM professionals in the United States. The holistic integration of BIM was regarded as the most practical solution. According to this guideline, the curriculum of construction engineering and management programs should offer a stand-alone BIM course in the first two years to introduce students to the basic BIM concepts and to teach them how to read, manage and interpret the models. In further years, the BIM model should form an integral part of existing courses (Lee,Dossick & Foley, 2013). Figure 2.7 summarises this approach diagrammatically.

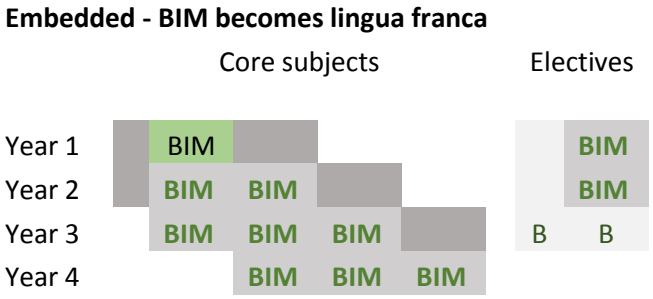


Figure 7 Curriculum model - Embedded

1.2.4 Cross-disciplinary dimension

Considering that BIM may facilitate collaboration among disciplines, developing BIM curriculm within an inter-disciplinary mode of delivery was considered a reflection of the shift in the industry towards integrated project delivery (IPD) (Becerik-Gerber, Gerber & Ku, 2011). The aim of team based learning was the industry manifestation of IPD (Zhao et al. 2013). Multi-disciplinary collaboration was elevated to the ultimate learning outcome in several curriculum frameworks (Barison et al., 2010; BIM Academic Forum UK, 2013; Mills et al., 2013).

In general authors referred to and reported on collaboration within the architecture, engineering and construction disciplines. However, Miller (Miller et al., 2013) proposed an extension of the boundaries of collaboration beyond the AEC domain to include the software and technology, business, enterprise and management disciplines due to the impact of BIM on the conventional project and business structures. It was suggested that a link to the social sciences could also be beneficial, due to the effect of BIM on communication practices and human behaviours (BIM Academic Forum UK, 2013).

Cross-disciplinary teaching could be regarded as an additional dimension to the teaching of BIM at universities. Joint-disciplinary implementation of BIM could take place within a single course or stream-lined over several years.

One example of a single-course collaborative BIM course was the joint-disciplinary BIM based course in construction management and structural engineering introduced at the Colorado State University (Richards & Clevenger, 2011). Delivery was via a video providing demonstrating the information accessible in BIM and a “self-guided e-learning assessment” in which students gained experience in manipulating the software and extracting data such as costs material and labour. Assessments were tailored to the two disciplines. No information was provided on the year in which this course was offered.

An interdisciplinary (AE) design studio course was also offered at the University of Wyoming (Hedges & Denzer 2008). An Australian example was found in the senior year offering at the University of New South Wales (AE) (Plume & Mitchell, 2007). There was also an example in the University of South Australia combined architecture and construction management (AC) course entitled Integrated Project which exemplified the ‘Collaboration’ component of the IMAC model which piloted the CODEBIM IMAC model in 2013. The Pennsylvania State University developed a stream-lined interdisciplinary program to address the real world scenario of IPD. The university piloted a three year cross-disciplinary (architecture and engineering) with strong industry support (Solnosky, Parfitt & Holland, 2013).

This type of approach to curriculum design and delivery requires extensive collaboration between the the Schools/Departments that own the programs if they are located in different institutional units. Typically architecture, construction and engineering programs are not located within the same unit

and this is one of the most significant barriers to teaching BIM as a collaboration tool. Teaching collaboratively across the built environment disciplines has been a discussion point in academia for more than two decades regardless of the emergence of BIM and it dates back to constructability and buildability research projects in the mid 1990s in the UK, Australia and the US. BIM may be a catalyst for greater integration between the disciplines. Three other important inter related considerations that would contribute to advancement in this area include; accreditation bodies requiring evidenced collaboration as a learning outcome, strengthened preparatory BIM courses to develop a baseline in skills and meaningful integration projects that require the core capabilities of each discipline to be demonstrated in the assessments.

1.2.5 Review of BIM curriculum content and strategies

There seemed to be evidence that BIM should be taught as the vehicle and not as the learning outcome (Mills et al., 2013; Sacks & Pikas, 2013). BIM teaching methodologies were reviewed by Barison and Santos (2010) and examples of using BIM in course work to enhance student learning have been published (Ahn, Cho & Lee, 2013; Clevenger, Glick & del Puerto, 2012; Hyatt, 2011; Kim, 2012; Liu & Hatipkarasulu, 2014; Poerschke et al., 2010; Richards & Clevenger, 2011; Shen et al., 2012). In addition, a proposal for the integration of BIM into construction topics and course work has been presented (Lee & Dossick, 2012). It is believed that prerequisites for any BIM course should be a basic understanding of construction drawing principles and building technology/science/ professional practice, programming language and data modelling concepts (Barison & Santos, 2010).

Curriculum content

The needs of the industry in the US have been researched frequently. As early as 2008, Gier (2008) established the need to teach BIM in construction management course in the USA through a survey of construction companies and academics. An online survey of several hundred construction practitioners in the USA found that education for construction management students should focus on the ***analysis of construction and design efficiencies*** through models and less on actual manipulation skills (Mutai & Guidera, 2010). According to a later survey of BIM professional in the United States (Lee, Dossick & Foley, 2013), undergraduates students should learn how to use the 3-D interface for ***interference (otherwise referred to as clash) detection*** of mechanical, electrical, plumbing and fire safety systems. Students should learn how to ***sequence construction activities*** to enable ***optimal time and cost efficiencies***. In addition students should be familiar with the ***changes in the construction process*** as a result of the increasing use of BIM in the industry.

Educational activities with other AEC students were recommended to learn ***collaboration skills*** (Lee, Dossick & Foley, 2013). A more recent survey (McCuen, 2014) of 31 construction companies in the US, found that construction companies ranked ***visualisation*** **and** ***constructability*** as the two most important graduate competencies to meet the immediate needs. For future industry needs, BIM competence around ***estimating*** and ***cost control*** were ranked highest (McCuen, 2014). In general, there seemed to be a consensus that the teaching of BIM should be **independent** of the platform or specific software, convey trends in **building information modelling and its processes,** how to **import and export specific data** and how to **share the information** (Lee & Hollar 2013). There is also an understanding that BIM education should address both buildings and infrastructure and that teaching institutions needed to keep abreast of changing BIM technology and industry requirements (BIM Academic Forum UK 2013).

A review of construction programs in American schools in 2009 (Becerik-Gerber, Gerber & Ku 2011) found that BIM in construction management courses was found to focus on constructability, 4D (time) scheduling, and model based estimation. Design, visualisation, sustainability and cost control was found to be part in over 40% of the programs, while multi-disciplinary collaboration was part of the programs in over half of the surveyed schools. Surprisingly, interdisciplinary teamwork was found to be less prominent in construction management programs (53%) than across all disciplines (56%) (Becerik-Gerber, Gerber & Ku 2011).

The most common BIM topics taught in construction management courses were constructability, model based estimating, design and visualisation, which were contained in over 50% of the courses (Becerik-Gerber, Gerber & Ku, 2011) as analysed by (Pikas, Sacks & Hazzan, 2013).

1.2.6 Curriculum design strategy: sequential learning & industry connectedness

There also seemed to be consensus that BIM education should be rooted in sequential learning, allowing the progressive build-up of levels of learning/ achievement as students advance through their education (BIM Academic Forum UK, 2013). The curriculum should focus on "developing the transferable skills of collaboration and technical capability" (Mills et al., 2013, p. 23).

Barison (Barison et al, 2010) believed in an introduction of BIM concepts at early stage, to give first year students good foundational knowledge of technical and conceptual application of BIM as a tool so that they could transfer their knowledge to other tools (Barison et al, 2010). Achievement of BIM proficiency during the first years should be followed by the application of BIM specific functionalities in specialised courses and topics. Researchers (Barison et al, 2010; Sacks & Pikas, 2013) recommended introductory course in Years 1 and/or 2, focussing on individual skill development and model analysis in digital graphic representation. These courses could be discipline-focussed. Typical tasks would be the development of a model of a small building, its manipulation and taking quantities off it.

In the intermediary years the focus should shift to collaboration in design and building technology courses with each team member being assigned specific roles; construction management students would provide input through evaluation of constructability of the design, clash detection and assessment of design options in relation to scheduling sequences and impact upon cost. Tasks from architecture and engineering disciplines would include advanced 3D modelling and visualisation, energy, lighting and structural analyses.

In an advanced level, such as the final year, BIM curriculum content should emphasise work on real projects in management courses or in interdisciplinary collaborative course ideally with student from other programs. Tasks should focus on BIM related processes and interoperability. Progressive "reinforcement" of BIM skills was considered as a viable strategy to a BIM embedded curriculum (Azhar, Sattineni & Hein, 2010). It was believed that a continuous use of BIM throughout all years and across courses would also mitigate skill loss (Maghiar 2014; Pikas, Sacks & Hazzan, 2013).

The review of construction programs in American schools in 2009 mentioned earlier (Becerik-Gerber, Gerber & Ku 2011) found that courses containing aspects of BIM were present in all years of education, yet the BIM content was found to be largest in the final year. Contrary to espoused philosophy on graduate profiles, the review found that most construction courses with BIM content were electives; only half of the construction management programs had compulsory BIM containing courses at undergraduate level (remembering that although electives provide diversity they also diminish the educators ability to manage graduate profiles). Majoring in BIM was not available as a course path in any of the architectural, engineering or construction management courses.

It was suggested that real life learning, "authentic learning and situated cognition" (Miller et al., 2013) should have a high priority in BIM curricula by "providing wider industry context and background" (BIM Academic Forum UK 2013). In the US, student “interaction with stakeholders from the real world" was found to be one of the most common goals of BIM inclusive courses (Barison et al., 2010) and judged to be the “best approach” (Molavi & Shapoorian, 2013). Sacks (Sacks & Pikas, 2013; p. 4) suggested that exposure to real life projects and industry could "mitigate the abstractions of BIM education". However Sacks acknowledged that BIM mastery at the highest levels of Bloom’s taxonomy, i.e. synthesis and evaluation, could only be achieved through actual experience. An example of real-life project based learning (PBL) was a final year elective undergraduate course in which the results of a BIM energy analysis were compared with actual metered performance (Shen et al., 2012). Another example was the Construction Management Final year - Construction & Fire Engineering course at the University of South Australia, in which the study of the BIM model for fire engineering was supported by site visits to the building under construction (Mills, J et al. 2013).

Teaching methodologies, as reviewed by Barison et al. (Barison et al., 2010) included a mixture or lectures, workshops, occasionally supplemented by audio and video files, groups tasks for modelling separate aspects and then integrating them, site visits to BIM offices and buildings as well as communication with BIM professionals in the industry.

1.2.7 Summary of Critical gaps

A systematic review of the effectiveness of BIM on student learning outcomes was not found. Two examples of testing the effectiveness of BIM showed promising results.

1. A teaching experiment that showed that the use of BIM as a teaching tool in a core introductory construction course enhanced the students' understanding of constructive details and quantity take-off (Kim, 2012). The core used progressive skill development by first exploring 2-dimensional CAD drawings, then developing a three-dimensional BIM model for visualisation of detail and finally using the BIM model for taking off material quantities. The comparison of the assessed learning outcomes of students who experienced this course with previous students who had been taught using conventional two-dimensional educational activities revealed better learning results in the BIM-taught student cohort (Kim, 2012).

2. Long term experiences with BIM in higher education were rare in the literature. Only the University of Texas at Austin presented its long term experience with a project management course. This project-based BIM course with a focus on life cycle thinking in construction was taught for five years. The delivery included lectures, group exercises, practical BIM exercises, case study, presentations and a final report. The evaluation of the course highlighted the significance of teaching BIM "as a process rather than a product" (Wang & Leite, 2014). Prior industry experience was found to assist in the understanding of the benefits and limitations of BIM. An increasing number of students were found to be familiar with BIM (Wang & Leite, 2014).

In terms of BIM curriculum content, BIM in the context of internationalisation was rarely a subject of the discussion. However, BIM could promote distance collaboration (Barison & Santos, 2010). There seemed to be agreement that BIM education should cover all aspects of BIM, namely ***people/culture/ project team roles*** (psychological and social skills), ***processes/ management processes*** (conceptual skills) and ***technology/software skills*** needed to be considered in a balanced manner (Barison & Santos, 2010; BIM Academic Forum UK, 2013; Macdonald, 2011; Sacks & Pikas, 2013). This goal did not seem to have yet been achieved in the US. Examining the syllabi of 18 BIM courses of seven US universities Sacks (Sacks & Pikas 2013) found that the courses emphasised technological and collaborative learning and that management specific BIM topics, e.g. ***standardisation, contractual aspects, data and information security*** as well as ***change management***, were neglected. Such a comprehensive approach to content and curriculum design is espoused by all leading authorities and yet these capabilities around core aspects of construction management theory (such as construction information flow, procurement, legal, contractual, regulatory, subcontractor management, business management and strategy and leadership/change management) are not yet evident in institutions. Merging the idea of what does it mean to be a construction management graduate without BIM capabilities and what does it mean to cross over a threshold and now be a BIM 'aware' or 'proficient' graduate is yet to be fully comprehended taking into consideration all the various areas that have not yet been addressed in curriculum content.

With regards to the process of developing curricula in universities, researchers agreed that each institution would need to develop its own approach, based on current BIM content in the curriculum, available infrastructure and current staff skills (Williams and Lees, 2009, p8 as cited in BIM Academic Forum UK, 2013). Learning outcomes and targets levels should also be determined on the basis of local industry needs and the students' existing knowledge (Sacks & Pikas, 2013). There were examples in the literature where the process of curriculum development was explained as part of a research project and yet there was little discussion from an educational perspective on curriculum design or redesign strategies.

1.3 Outcome 2 Theoretical discourse on Threshold concept

The literature review in Section 2 raised interesting issues in relation to both curriculum design or redesign to include BIM content and BIM learning outcomes or threshold capabilities. It is important that we also consider more deeply discourse in higher education literature in these key areas; curriculum design and learning outcomes. This review was limited to the formal and planned curricula in tertiary education as represented in a written document or time table. Curricula can be organized into three major components: objectives, content or subject matter and learning experiences (Lunenburg, 2011). The review has excluded the informal curriculum, which consists of supplementary student services, and the hidden curriculum, which consists of underlying assumptions and attitudes (Leask, 2013). The review is organised into four main sections; a background to the underlying concepts in the current discourse of curriculum development, outcomes based education and learning outcomes, the threshold concept theory and the process of curriculum design.

1.3.1 Underlying concepts of curriculum discourse

There were two overarching discourses in the literature including the traditional, teacher led curriculum vs the outcome – based education and then various debates within the broad framework of curriculum structure and the factors that affect structure, including interdisciplinary vs disciplinary balances, sequential learning with *cognitive coherence* vs flexible open and modular curriculum based upon *learning outcomes*.

Firstly, the literature distinguished between the traditional, teacher-led curriculum and the currently dominant approach in higher education in the developed world, the outcome-led curriculum design. The traditional approach was a teacher-focussed educational process in which the teachers' expertise and interests determined the content of the courses and the program (Allan, 1996). In a teacher-led curriculum, curriculum planning took a secondary role. By contrast, an outcome-based curriculum was characterised by its designed structure and its focus on the learning of the student. This review has concentrated on outcome-based education (OBE) and its key concepts in curriculum design.

A second debate around higher education centred on the disciplinary discourse. The discussion focussed on the question on how far university education should be characterised by an open and interdisciplinary learning experience or be discipline bound. Ensor (Ensor, 2004) distinguished between the 'disciplinary discourse' and the 'credit exchange discourse'. The disciplinary discourse favoured a curriculum that was characterised by sequential learning and self-preoccupied orientation within the bounds of a discipline with the aim to provide 'cognitive coherence'. Ensor linked this model to the teacher-led learning experience with a vertical teacher-student relation (Ensor, 2004).

By contrast, the credit exchange, credit accumulation and transfer discourse was characterised by an open, interdisciplinary and modular curriculum that offered flexibility and was guided by learning outcomes. Ensor (2004) explained that proponents of this model justified this approach by the increased globalisation and the call for work-ready graduates (Ensor, 2004). As such it was closely linked to the shift in higher education to OBE.

An ultimate example was the completely open curriculum of Brown University (Brown University 2014), in which students were able to compose all elements of their curriculum themselves. An example of a more open curriculum design in Australia was the 'Melbourne Model' (Melbourne, 2014) that offered flexible course choices within a broadly defined undergraduate degree and subsequent professional course degrees. The credit exchange approach is often a strategy with the design of postgraduate education to enhance flexibility and also because students are often originating from diverse disciplines in postgraduate courses; the first online Australian Masters of Construction Management program which Professor London designed is an example of this.

In more open curricula, universities needed to monitor the range and sequence of courses students took to ensure that students achieved the desired learning outcomes (The National Academy for Academic Leadership 2014). While the open curriculum offered the students maximum flexibility, the credit accumulation model could be problematic in the time-tabling of desired courses and in the validity of the undergraduate qualification. As education progress in an open curriculum was

measured in the number and length of courses taken without consideration of course specific contents or outcomes, the open curriculum assumed that the graduate learning outcomes were proportional to the sum of prescribed hours and course credit points (Diamond, 2008). This assumption could only be defended if a uniform distribution and progression of learning outcomes across all courses and year levels was ensured. Without a strict or prescribed curriculum structure in open curricula, academic advising became more important to guide students' educational development and achievement (The National Academy for Academic Leadership 2014). The overall coherence and consistency of the learning outcomes in the courses was critical and staff training in the delivery to the learning outcomes was also critical – the challenge is that over time the elements become eroded as the original team in place become fragmented and thus the coherence of the delivery becomes fragmented. Documentation to support the philosophy of the program is important.

Mixtures of the two approaches is possible. For example, courses could be ordered in a predefined sequence with pre-requisites for subsequent courses with a small part of the curriculum given over to electives (Brawley et al. 2013). The curriculum discourse prevalent in a nation or institution led to distinctive variations in graduate learning outcomes (Sweetman, Hovdhaugen & Karlsen, 2014). The decision on the philosophy of education was considered to be the first step in the development of a new curriculum (The National Academy for Academic Leadership 2014).

1.3.2 Origins, principles and criticisms of OBE curricula

Outcome based education and its application in the 21st century were driven by societal demands for accountability and quality assurance (Diamond, 2008). Outcome or Competency Based Education (OBE) addresses individual achievements at hierarchical levels and was characterised by the learner-centred approach. OBE had its roots in the educational discourses of behavioural objectives of Tyler (1949). This model was further developed by Bloom who posited that the aim of teaching should manifest in intended behaviours of the student that should be clearly communicated. Bloom developed a taxonomy to distinguish between the cognitive, affective and psychomotor domains and identified a hierarchy of successive learning levels (Bloom, 1956). It also had significant contributions by Gagne and Briggs (1974) and the instructional design models by Mager (1997). Spady (1994) was called the revivalist or key advocate of the objectives-based education model (Baumgartner & Shankararaman, 2013; Morcke, Dornan & Eika, 2013). According to Spady (1994, p. 2) outcomes should reflect what the student has learned and be observable. Affective outcomes such as "values, beliefs, attitudes and psychological states of mind" were seen as preconditions or goals and expressly excluded because of the difficulty in directly assessing them (Spady 1994, p. 2).

One development was the emergence of the term 'competency'. Although the terms 'outcomes' and 'competencies' were often used interchangeably and there did not seem to be universally accepted or used definitions, some researchers distinguished between the two terms. The most common reference was the definition for competencies by Albanese et al. (2008) who extended the characteristics of outcomes that were originally defined by Harden et al. (Harden, Crosby & Davis, 1999). Harden et al. (1999) specified that outcomes should "reflect the vision and mission of the institution", be "clear and unambiguous", "specific", "manageable", "defined at an appropriate level of generality", "assist with the development of 'enabling' outcomes" and "indicate a relationship between the different outcomes" (Harden, Crosby & Davis, 1999, p. 546). According to Albanese et al. (2008) competencies should also "focus on the performance of the end-product or goal-state of instruction", "reflect expectations that are an application of what is learned in the immediate instructional programme", "be expressible in terms of measurable behaviour", "use a standard for judging competence that is not dependent upon the performance of other learners" and "inform learners, as well as other stakeholders, about what is expected of them". While both approaches required pre-identified intended results of the education, competencies had a broader, more conceptual connotation that embraced cognitive abilities and individual character attributes and were manifested in the successful execution of tasks (Baumgartner & Shankararaman, 2013; Frank et al., 2010; Gruppen, Mangrulkar & Kolars, 2012; Morcke, Dornan & Eika, 2013; Succar, Sher & Williams, 2013). Considering the ambiguity of the term 'outcomes' and 'competency', this document adopts the common strategy (e.g. (Morcke, Dornan & Eika, 2013) and use the term OBE to refer to both outcome and competency based education.

OBE has governed tertiary education in the USA, South Africa, Australia, Europe and more recently was introduced in Hong Kong (Baumgartner & Shankararaman, 2013; Luk & Chan, 2013). The benefits of OBE were claimed to be the ability for educational outcomes to be aligned to global and international standards, the use of learning outcomes as a means to evaluate the quality of the educational attainment and to cater for student mobility (Ewell, 2008).

Criticisms of OBE

OBE was not without criticism. It was argued that OBE's focus on the pre-specified learning outcomes and behavioural objectives as opposed to education as a process limited the education and optimisation of student learning to mere training (Stenhouse, 1975), prevented or inhibited wider learning (Hardarson, 2011), autonomous learning, questioning and communication with the teacher (Maher, 2004). In addition it was argued that OBE, which targets standardised outcomes, rewarded adequate performance while it could not acknowledge excellency in students (Talbot, 2004). Others perceived OBE standards as a threat to academic freedom (Uchiyama & Radin, 2008). As learning outcomes had to be observable, formally assessed and unchanging over the period of the educational experience, their validity in more creative or unquantifiable disciplines remained problematic (Tam, 2014). Taking an economic philosophical viewpoint, Olssen and Peters (2005) criticised the market-orientation of the OBE approach as the manifestation of neoliberalism in which universities became educational factories with knowledge as capital.

OBE was a prominent topic of discussion in medical education with an ongoing debate on its relevance and value (Morcke, Dornan & Eika, 2013). The pursuit for a curriculum theory that adequately placed equal focus on cognitive and affective outcomes and internalised social, cultural or professional attributes and learning experiences, that fostered professional attitudes such as humanism, accountability and altruism, and that adequately conveyed the constructivist learning theory, is continuing (Morcke, Dornan & Eika, 2013). A review of the effect of OBE on learning and teaching in medical education revealed a dearth of research on the learning effectiveness of OBE, on student and teacher satisfaction and on the most effective use of learning outcomes for teachers and students (Brooks et al., 2014; Morcke, Dornan & Eika, 2013). The limited evidence showed that teachers planned their courses on the school level's predetermined learning outcomes but that participation learning was hindered. The relevance of the actual learning results for the specified courses' proclaimed learning outcomes was unclear (Morcke, Dornan & Eika, 2013).

1.3.3 OBE, Learning Outcomes and Critique

Harden, Crosby and Davis (Harden, Crosby & Davis, 1999) have been credited with extending the OBE approach to the concept of rational and formal curriculum design. OBE was characterised by a rational, top-down design of the curriculum that started with the definition of what the student learnt, the learning outcomes or competencies, and by making the requirements for expected capability acquisition explicit (Kift, 2002). Learning outcomes were the drivers of OBE curriculum designs.

Learning outcomes were the starting and end point of a program curriculum design. The identification of learning outcomes frequently includes consultation with external stakeholders (Robley, Whittle & Murdoch-Eaton, 2005a). Student perceptions about the validity of the skills and their categorisation were likely to be different from those of the teachers (Lucas et al., 2004).

The literature distinguished between declared, taught, learned (English, 1978) and assessed (Robley, Whittle & Murdoch-Eaton, 2005b). The articulated curriculum proposed by Hussey et al (2003) also introduced intended and emergent, predicted and unpredicted, and desirable and undesirable learning outcomes as a reaction to learning outcomes that were believed to have "become so entangled with notions of specificity, transparency and measurability as to become largely irrelevant to classroom activities and practices, as well as being unachievable" (p367).

In general, the literature on curriculum design referred to intended or desired learning outcomes without specifically defining them. Learning outcomes were supposed to be clear statements of what the learners would be able to:

> • *"Know and understand in terms of content, knowledge, principles, concepts, and theories;*

- *Do in terms of skills and competencies;*
- *Develop in terms of attitudes and values." (Anderson & Rogan 2011, p. 69).*

Guides for writing unambiguous learning outcomes, which were driven by the verb, were published (Biggs & Tang, 2010; Kennedy, 2007; Tam, 2014). Learning outcomes were often structured according to Bloom's taxonomy (Kennedy, 2007; Lozano, Ceulemans, Scarff & Seatter, 2014). Despite the wide-spread employment of learning outcomes in higher education, their use was not without criticism.

OBE curriculum designs were characterised by the constructive alignment of a tiered and comprehensive framework of learning outcomes. Learning outcomes represented "what is formally assessed and accredited to the student" (Allan, 1996; p93). The theory of Constructive Alignment (CA) combined educational constructivist theory with the alignment of learning outcomes from their definition to their evaluation (Biggs, 1999; Biggs & Tang, 2010). The coherence between the predefined, clear and unambiguous learning outcomes at all levels, the program and course contents, teaching and learning methodologies, learning assessments and curriculum evaluation as well as the static nature of learning outcomes over the period of the educational experience, were seen as the key to the success of an OBE framework and for the effective accountability of educational institutions (Diamond, 2008; Tam, 2014).

Within the OBE framework, universities were linked in the hierarchical chain between national educational frameworks and societal requirements from industry and accreditation bodies on the one side and the individual student on the other. Learning outcomes were defined at the national, university, program, sometimes year and individual course levels. The National Australian Qualification Framework (AQF) defined learning outcomes for all levels of formal education and has set standards for both university wide 'graduate attribute' (or 'profiles') and for Bachelor programs. The Australian Qualifications Framework defined learning outcomes as " the expression of the set of knowledge, skills and the application of the knowledge and skills a person had acquired and was able to demonstrate as a result of learning" (Australian Qualifications Framework Council, 2013; p97).

Graduate profiles were determined individually by each university. The AQF specified that universities had to define learning outcomes in the domains of 'people', 'fundamental', 'thinking' and 'personal skills'. Universities interpreted these regulations individually to outline their graduate attributes that were independent of disciplinary knowledge and applicable to all undergraduate degrees that were on offer.

Anderson and Rogan (Anderson & Rogan, 2011) explained the key success factors and rationale behind the concept of learning outcomes. They posited that "objectives and learning outcomes need to be compatible with the goals but also clearly defined, realistic, and achievable by students. In this regard, there was a world-wide trend toward an emphasis on the understanding of core knowledge, critical, and threshold concepts, and key skills, rather than overloading students with excessive information that encouraged rote learning (Anderson & Rogan, 2011; p69). Program or degree related learning outcomes were developed to reflect the generic university graduate learning outcomes, those stipulated by the AQF within the context of the discipline and to meet the reviewing criteria of professional accreditation associations (Diamond, 2008). Learning outcomes were further differentiated into learning outcomes specific for each year level of a bachelor degree and tiered (Baumgartner & Shankararaman, 2013). Course learning outcomes described what the student learnt in a particular course and how it contributed to the achievement of the year or program learning outcomes. According to Biggs (Biggs & Tang, 2010; p3), learning outcomes at program and course level needed to include three distinctive components: "a statement of what the student is supposed to be able to do at the end of the programme or unit, a verb; the content area to which the verb applies; or the levels of understanding or performance in those content areas that are to be achieved."

One of the claimed benefits of OBE in a globalised economy was that the education was assessable and portable. However, the objective of having generic learning outcomes as a way of comparing and ranking higher education institutions as envisaged in the European curriculum reform proved difficult because of a diversity of national and disciplinary definitions (Sweetman, Hovdhaugen & Karlsen,

2014). In addition, with regards to the internationalisation of education, constructive alignment could not be assumed in all nations (Baumgartner & Shankararaman, 2013; Richard, Coll & Taylor, 2013). A scoping review of engineering education, which has international recognition through the Washington Accord, found that there was still some uncertainty about the equivalence of learning outcomes especially concerning the final year research capstone project (Thambyah, 2011). A consensus for requirements for construction engineers competencies for Hong Kong and Mainland China has been reached (King, Duan & Wang, 2013).

Criticism of Learning Outcomes approach

Criticism of learning outcomes seemed to have been largely rooted in the ambiguity in the use of the term, and there was a debate on how vague or specific their prescription should be (Prøitz, 2010). On the one hand, Hussey and Smith (2002) argued that learning outcomes were generally too vague and too reliant on interpretation to be meaningful to the student. Hence learning outcomes might be most useful in a course level, in a small and well-defined setting in which the teacher conveyed the intended outcomes of the course or teaching period (Hussey & Smith, 2002). On the other hand, the same authors claimed that learning outcomes that were too tight or too specific and were communicated as 'threshold achievements' would inhibit student ingenuity and ambition (Hussey, Trevor & Smith, 2003). The problem seemed to be in the use of the generic term learning outcomes at the different levels of the curriculum. A possible solution might be to differentiate between learning outcomes at program level and competencies at course level (Baumgartner & Shankararaman, 2013). The Australian Qualifications Framework has clearly designated the terminology at Program Learning Outcomes (AQF, 2013) and RMIT has Program Learning Outcomes (broad and high level) and Course Learning Outcomes (focussed on topic and specific).

Criticism of learning outcomes also stemmed from their universal application across disciplines and their focus on well-established answers or solutions. Some education researchers questioned the underlying rationale of learning outcome design on convergent thinking. They believed that pre-specified learning outcomes neglected the acknowledgement of divergent thinking that was desirable in the creative disciplines (Hardinghaus, 2006). Furthermore, the use of the level descriptor of Bloom's taxonomy was critiqued as being too simplistic, for presuming a linear learning process and for failing to recognise that the levels of cognitive achievement were attained at different points in time depending on the disciplines (Hussey, Trevor & Smith, 2003). Last but not least, researchers doubted the acceptance of learning outcomes by higher education teachers and their validity. Maher (2004) warned that learning outcomes might "become meaningless and even detrimental to the educational process" if used by teachers as a "learning outcomes games". Others argued that learning outcomes were primarily an administrative construct as their claim to precision, specificity and assess-ability could not be upheld (Hussey & Smith, 2002).

Hence, it was suggested that learning outcomes should be guided by flexibility rather than dictation, that teachers should be open to emerging and incidental learning outcomes and that non-education trained teachers, such as industry experts, should be educated in the concepts of learning (Maher, 2004). Prøitz (2010) concluded that the debate on the purpose and validity of learning outcomes that has spanned four decades has not been resolved. The Threshold Concept theory offered an alternative approach to learning outcomes when structuring a curriculum in higher education.

1.3.4 Threshold concept theory: criticisms and application

Threshold concepts were "critical points in a student's learning" (Barradell, 2012; p268). Despite the growing popularity of the Threshold Concept theory since its conception a decade ago, it was critiqued for its lack of maturity (Tight, 2014b). Due to the focus of the threshold concept theory to disciplinary content, its application to outcome-based curricula was considered to be strained. Recent efforts were made to better integrate the threshold concept into current curriculum design approaches.

First advocated by Meyer and Land (2003), threshold concepts "can be considered as akin to a portal, opening up a new and previously inaccessible way of thinking about something" (Meyer & Land, 2003; p1). Based on the concept of 'troublesome knowledge', thresholds might be linked to '*transformative*', '*irreversible', 'integrative', 'bounded'* and '*troublesome'* advances in a student's learning process (Meyer & Land, 2003). The criteria *'discursive'* and *'reconstitutive'* were added a

decade later (Barradell, 2012; Land, Rattray & Vivian, 2014). Central to the threshold concept theory was that learners might be in a state of liminality before they understood and crossed the threshold. Liminality is the condition in which learners took note of the threshold concept without yet being able to grasp or fully understand it, it relates to a transitional or initial stage of a process and people occupy a state of liminality at, or on both sides of, a boundary or threshold. This cognitive block might cause anxiety. The crossing of the threshold, the point of understanding, might include a shift in the learner's perception and world-view (Land, Rattray & Vivian, 2014; Meyer & Land, 2003).

It was argued that the benefit of using the thresholds concept as the framework for curriculum design might facilitate a more efficient and succinct curriculum that was mindful of the non-linear nature of learning and the need to allow students time to comprehend certain concepts fully (Cousin, 2006). While thresholds primarily addressed the content of the teaching, the underlying objective of the threshold theory was the provision of optimum support of the student's educational experience that extended the theory into teaching practice (Barradell, 2012).

Criticisms of Thresholds concept Theory

Critics of the thresholds concept theory found the arbitrariness and the lack of rigour in the identification of thresholds problematic (Barradell, 2012; O'Donnell, 2010; Tight, 2014b). As many of Meyer and Land's (2003) criteria for threshold concepts had been accompanied by the terms 'probably' or 'potentially' , and as the seven criteria had not been weighted, critics found fault with the vagueness in expression and claimed that the criteria offered little guidance for the identification of thresholds. Tight also questioned the validity of thresholds when they were defined by educators (Tight, 2014b). A more robust and universal approach to identifying threshold concepts was called for (Quinlan et al., 2013). Barradell (2012) proposed a 'transactional curriculum inquiry' that included all stakeholders, i.e. teaching staff, students and external stakeholders.

By reviewing examples of thresholds concept applications in the literature, Tight (2014b) also sensed a second problem in the diversity in which thresholds had been applied, namely to specific, disciplinary processes (e.g. recording of a complete dental jaw registration), cognitive processes (e.g. systems thinking) or generic processes (e.g. writing). Researchers also questioned the underlying assumption of the universality of thresholds for all students and in all contexts (Rowbottom, 2007; Tight, 2014b). Lastly a review of published adoptions of threshold concept theory in higher education found that it was not clear if and how the identification of threshold concepts had changed existing delivery methods (Tight, 2014b).

It should be noted that thresholds are distinct from core competencies. The teaching of core competencies is a continuum that is paced throughout the curriculum as manifested in progressive year level learning outcomes. Curricula which are designed around thresholds focus on a few points in time in the cognitive learning process. These may not occur at regular intervals and the timing may vary from one student to the next. Both approaches aim for the gradual improvement of the student. However, a curriculum based on the gradual development of core skills may lend itself better to the temporal planning of teaching and learning of knowledge. The timing of teaching threshold concepts could be at regular intervals in order not to overburden the student, or could be heaped within one period with other periods being devoid of them. A discussion of the appropriate timing of teaching threshold concepts is missing in the literature.

Application of Thresholds concept

The thresholds concept theory has been applied in disciplines including the sciences, health care, literature business, law and social studies (Tight, 2014b). While it would be beyond the scope of this paper to review all applications, one Australian example in engineering education is presented here.

An Australian team of educators at the University of Western Australia combined the threshold concept with capability and variation theory into the Threshold Capability Integrated Theoretical Framework (Baillie et al., 2012a). For Bailie et al. (2012) the thresholds concept had the advantage of making apparent implicit learning concepts which facilitated the focus on the most important steps in the students' learning progress, the most appropriate educational experience and the best assessment methods (Baillie et al., 2012a). Capability theory is concerned with teaching students capabilities to deal with unforeseeable future events and problems (Bowden, 2004). Capabilities were merged with the threshold concept as the elements that were deemed troublesome were not always

disciplinary concepts but included capabilities to cope with new situations (Baillie, Bowden & Meyer, 2013). While in the threshold concept theory the disciplinary knowledge content is driving the structure of a curriculum, curriculum design based on capability theory focusses more on situational and progressive learning and the requirement of fundamental cognitive attitudes that are seen to be essential in becoming successful professionals (Åkerlind, McKenzie & Lupton, 2014; Bowden, 2004). Based on the Threshold Capability Integrated Theoretical Framework the following questions guide a curriculum design process:

> *1. "What should the learner be capable of doing at the end, given the need to deal with an unknown future?*
>
> *2. What threshold concepts are important to understand to enable the development of such capability?*
>
> *3. What kinds of learning experiences and in what combination would best assist the learner to develop interim threshold capabilities and ultimately build on them to develop the capability to handle the unknown future after graduation?*
>
> *4. How can the learning environment be best arranged to provide access to those optimal capability development experiences?*
>
> *5. How can the differing needs of individual students be catered for?*
>
> *6. What, specifically, is the role of teachers in supporting such learning by students?*
>
> *7. What kinds of assessment of student learning will motivate learning of the kind desired and authentically measure the levels of achievement of the intended learning outcomes?"(Baillie, Bowden & Meyer, 2013, p237).*

The Threshold Capability Integrated Theoretical Framework was used to develop a curriculum of a two-year engineering foundation course at the University of Western Australia (Baillie et al., 2012a). The need for a curriculum renewal was the high rate of attrition of engineering students (Baillie et al. 2012a).

The curriculum development process was iterative and took a ***phenomenographic action research design approach*** (Åkerlind, McKenzie & Lupton, 2014). The first step in the curriculum development process was the identification of learning outcomes by academics of the school. These were used as the basis to develop threshold concepts with consultation of a "reference group, project consultant, project evaluator", international educators with expertise in threshold concepts, students and teachers. The threshold concepts were linked logically as some capabilities were found to necessitate pre-requisite. For example, communication skills were considered a pre-requisite for team work (Baillie et al., 2012b).

These concepts were then grouped into the sequential categories for 'learning to become an engineer', 'thinking and understanding like an engineer' and for 'shaping the world as an engineer'. The origins of these three sections were not explained in any of the publications. They did not refer to year level outcomes but seemed to sit across all year levels. The Integrated Engineering Foundation Threshold Concept Inventory was a graphic illustration of the thresholds and capabilities mapped into the three sections (Baillie et al., 2012b). The previously identified learning outcomes were then assigned to thresholds. Several workshops assisted in the validation, confirmation and revision of thresholds. Finally thresholds were mapped to the courses and delivery methods, and delivery and assessment methods were recommended (Baillie et al., 2012b). The implementation of the new curriculum included the training of the educators of the courses on threshold concept theory (Baillie et al., 2012a) and communication of the definition of thresholds and in the course guides. The new curriculum was introduced in 2012. While teachers reported to have gained better understanding of

the threshold concept itself, of the students' perspective of learning the disciplinary content and of more effective teaching techniques, there was no conclusive evidence that the new curriculum improved student learning (Åkerlind, G, McKenzie & Lupton, 2014).

A further extension of the threshold concept was the integrative model developed by Barradell and Kennedy-Jones (2013). In this model the elements of threshold concepts, student learning and curriculum were combined, and the outcomes of ways of thinking and practising, liminality, meaningful learning and meta-learning were seen to happen at the intersections of the elements. The researchers argued that only the integration of the content-focussed thresholds into the other essential constructs of education, namely desired learning outcomes and learning processes, would provide students with the necessary educational foundation for their future professional life (Barradell & Kennedy-Jones 2013).

1.3.5 ALT Academic Standards: Building Discipline Threshold Learning Outcomes

In 2011 in Australia there was a national project funded by the Office of Learning and Teaching, "Learning and Teaching Academic Standards Project LTAS", which addressed discipline specific competencies. The Building discipline was part of the LTAS project and was one such discipline that developed such competencies. Interestingly Threshold Learning Outcomes (TLOs) were developed. The Threshold concept theory is explored in more detail later on in this section. Professor London was a member of the LTAS Building Discipline Reference Group representing the industry professional association Chartered Institute of Building who is an international accrediting organisation. Upon completion of a bachelor degree in building and construction, graduates will be able to:

1. *integrate and evaluate the fundamental principles and technical knowledge of building and construction technology, management, economics and law*

2. *identify and resolve typical building challenges with limited guidance, employing appropriate evidence-based problem-solving and decision-making methodologies*

3. *critically and creatively reflect on personal behaviours and capabilities in the context of entry to professional practice*

4. *interpret and negotiate building and construction information, instructions and ideas with various project stakeholders*

5. *research and develop methods and strategies for the procurement and delivery of contemporary construction work*

6. *demonstrate an integrated understanding of both the theory and practice of building and construction based on experience. (LTAS, 2011)*

Each TLO had specific additional notes and two are repeated here which are particularly pertinent to Building Information Modelling: Communication TLO 4 and Innovation TLO 5.

TLO 4 Communication is one of the broader themes that comprise the TLOs. Communication would typically be seen to span and contain various forms (oral, written, electronic etc), in different contexts (meetings, databases, hearings etc), and for particular purposes (technical, regulatory, social etc). Effective communication certainly involves more than just issuing information; it also requires good listening skills and the perceptiveness to recognise whether the intended message is actually being understood – and the ability to adjust the communication accordingly. Further, the actual capabilities for effective communication change across the continuum of potential project stakeholders, from technical experts through to the general public and non-builders. Whilst all aspects of communication are important, specific concern has been raised about the ability of graduates to interpret and negotiate information. This has resulted in a more contained TLO. The intention is that graduates, presented with a problematic situation or issue, should be capable of identifying the critical elements and negotiating with others to achieve a particular outcome. Negotiation is intended to cover a wide

range of possibilities, from formal negotiation settings to coherent and reasoned argument in written submissions.

TLO 5 Innovation Building and construction is a progressive industry which is not renowned for its innovation. Certainly, it is essential that graduates understand current industry development. There was broad concern, however, that ***graduates need to understand more than just the current industry practice****.* ***An awareness of emerging methods and strategies****, coupled with the capability to research and develop entirely new possibilities and redevelop or repurpose existing options, was considered an essential if innovation is to be supported and grown. Of particular note were the methods and strategies for procurement and project delivery. Whilst innovation should apply across the industry, the consensus was that research and development capabilities could most usefully be exercised in the specific application context of procurement management. Innovation generally refers to the creation or improvement of products, technologies or ideas but generally requires some formal structure to frame the process. Relevant research projects and case studies are obvious ways in which innovation might be evidenced. (LTAS, 2011; p11-12)*

1.3.6 Embedding a Specific Concept in an existing curriculum

The challenge of embedding Building Information Modelling into a program appears to be somewhat similar to the previous challenge of embedding sustainability into a program. Education for sustainability had become a worldwide priority and a thorough integration of sustainability into tertiary education was seen as critical (Hegarty et al., 2011). Five main approaches were identified for incorporating sustainable development into higher education undergraduate curricula (Lozano, Ceulemans & Scarff Seatter, 2014; Thomas, 2004)

1. Integration of some sustainability topics into existing courses
2. A stand-alone or dedicated course on sustainable development
3. Holistic integration of sustainability into the disciplinary program and all courses
4. Option of specialisation in sustainable development within the program framework
5. Sustainable development as an individual program

It was argued that stand alone sustainability courses into the framework of existing programs could facilitate an easy implementation but that students might not perceive the importance of the subject if it was dealt with outside the core modules (Thomas, 2004). It might however prove useful in the transition to a more embedded sustainability curriculum. The experience with a stand-alone, compulsory, inter-disciplinary course on sustainable development at RMIT University reportedly accelerated the transfer of skills and their adaptation into the context of the students' own disciplines (Hegarty et al., 2011).

In general, the integration of sustainable design into each module of an existing curriculum was considered the most effective approach (Abdul-Wahab, Abdulraheem & Hutchinson, 2003; Ceulemans & De Prins, 2010; Lozano, Ceulemans & Scarff Seatter, 2014). However, the Delft University of Technology adopted a three-pronged approach to the introduction of sustainable development into their curriculum:

> 1. *a compulsory* introductory course for all students,
> 2. the embedding of sustainable development concepts in all regu*lar disciplinary courses at the Delft University and*
> 3. *the provision of the possibility of specialisation within the framework of each faculty (Kamp 2006).*

The transition to fully embed sustainability into curricula was not without challenges. Resentment by staff of the top-down overall integration of sustainable development was reported in Dutch institutions. An individual consultation with lecturers was seen as being most successful in overcoming the scepticism of lecturers, retaining the lectures' perception of control and acknowledging the distinctive characteristics of the courses (Peet, Mulder & Bijma, 2004).

At RMIT the adoption of sustainability education has also been characterised by a top-down approach. The isolation of motivated staff and the reluctance of teachers to take consultation from outside their discipline were observed barriers to the successful integration. Staff development has been suggested as a way forward (Thomas, 2004). In general, key factors for the integration of sustainability into university curricula have been found to be a strong political commitment, adequate resourcing, and motivations of sustainability champions and individual staff education, continuous staff development and taking opportunities of changes (Holmberg et al., 2008; Ralph & Stubbs, 2013).

The creation of a specialised Bachelor of Engineering of Sustainable Development presented an interesting case study for new curriculum development (Lozano & Lozano, 2014). Stakeholder engagement included interviews with students, staff and potential employers with interest in the course and resulted in five key learning outcomes. The curriculum was developed by a committee composed of staff members and experts in various areas of sustainable development in engineering (Lozano & Lozano, 2014). The draft curriculum was validated and assessed by an expert in curriculum evaluation using the Sustainability Tool for Assessing Universities' Curricula Holistically (STAUNCH®) system (Lozano & Lozano, 2014).

1.3.7 The process of curriculum design and constructive alignment

Based on the premise of OBE, a rational approach to curricula and constructive alignment, guides to curriculum design have been published (Anderson & Rogan, 2011; Diamond, 2008). Central to the rational OBE curriculum design was the self-critical attitude that curricula needed to be continually improved through the evaluation of student learning outcomes. The design process should be rooted in the institution's teaching philosophy, be needs-based, goal driven, independently facilitated, teaching team supported, data driven, iterative and result in a possible rather than in an ideal curriculum (Diamond, 2008).

According to Diamond (2008) the pre-requisites for an effective curriculum revision were the presence of dedicated and qualified teaching staff and a supportive faculty. The need for a curriculum revision could arise from external factors, such as accreditation criteria, changes in the disciplinary domain, feedback from industry or graduates, internal factors, such as unsatisfactory student retention rates or curriculum assessment results. Diamond (2008) posited that success was more likely when there were explicit internal drivers of change, such as key individuals, willingness of staff participation and written institutional support and funding.

Diamond (2008) split the process of curriculum design into two phases, the revision of the program curriculum (Phase I) and the development of the curriculum at the course level (Phase II). On the premise that there was agreement on student-centred learning, he proposed to start the process of curriculum revision with a diagram illustrating the structure, flow and content of the curriculum (Diamond 2008). This process was at times called curriculum audit or curriculum mapping. The next step, data gathering, should address the nature of the students, the requirements and priorities of society and the institution itself, the focus of the discipline related knowledge and be collected from employers, past graduates, student recruiters and the literature. The data analysis was supposed to reveal variations in perceived priorities and in the perceived effectiveness of the current curriculum. Based on the findings, an ideal curriculum should be designed with focus on sequence and cohesion. The final stage of the curriculum design was to be the adjustment of the ideal to the possible program based on the necessary extent of the revisions and resource constraints. In Phase II, learning outcomes for individual courses should be developed, educational methodologies, activities and assessments assigned and tested. Continuous evaluation of curriculum outcomes should be used to revise and adjust the planned curriculum (Diamond, 2008).

Anderson and Rogan's (2011) guide focussed on Phase I and discussed the components in a sequential manner. In keeping with the theory of constructive alignment, however, curriculum development and design could focus on any aspect of the curriculum chain with consequences for the other components. According to them, the curriculum vision could be determined by "market demands; new niche areas that might give the institution a competitive edge; graduate attributes that employers would expect …. for competency in the work place and the expectations of any accreditation bodies or directive from policy makers" (Anderson & Rogan, 2011; p69). The identification of learning outcomes frequently included external stakeholders (Robley, Whittle,

Murdoch and Eaton, 2005a). Figure 3 illustrates the iterative process of curriculum design and revision that was influenced by external forces and validated by constant curriculum evaluation (Anderson & Rogan, 2011). The continuous management and revision of learning outcomes across programs and courses could be facilitated by electronic management systems (Baumgartner & Shankararaman, 2013).

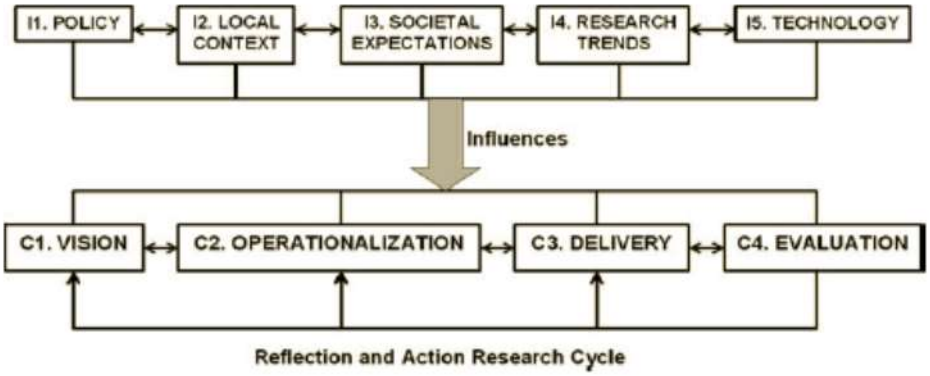


Figure 8 Flow diagram illustrating the dynamic and cyclical relationship between key components (C 1-4) of curriculum and related influencing factors (I 1-5). Source: (Anderson & Rogan 2011)

The implementation of the 'vision', that is the curriculum design development, should ensure the coherence and alignment of learning outcomes, educational activities and assessment and progressive learning (Anderson & Rogan 2011). Tam stressed that OBE curriculum planning started with the specification of "the most important skills and knowledge in a program or course" (Tam, 2014; p162).

Curriculum auditing/ mapping

Curriculum mapping refers to a systematic audit of some or all elements of a curriculum at institutional or program level. In the literature, the need for a curriculum mapping exercise predominantly arose due to external or top-down pressures to demonstrate alignment with institution graduate attributes or key concepts such as sustainability and employability. Other drivers were negative student feedback that pointed to inadequacies (overlapping and repetition) in course content (Uchiyama & Radin, 2008). The aims of curriculum mapping could be the demonstration of learning outcomes across a program, the links between learning outcomes and content within a program curriculum and making the curriculum structure more transparent for all stakeholders (Britton et al., 2008; Sumsion & Goodfellow, 2004). Communication and access to a mapping tool could guide students in their pathway and choice of courses in more flexible curricula (Tariq et al., 2004).

The literature revealed diverse purposes of auditing the curriculum at the disciplinary program level for educators, external stakeholders and students:

- Identification of components of curriculum and the relation between them (Harden, 2001)
- Display of alignment of learning outcomes, teaching and learning activities and assessment (Biggs, 1999) and identification of gaps (Krathwohl, 2002)
- Display of the progress, alignment, completeness and gaps of the dimensions of knowledge and cognitive processes and the subcategories of factual, conceptual, procedural and metacognitive knowledge and the cognitive processes of remembering, understanding, application, analysis, evaluation and creation in an existing curriculum (Krathwohl, 2002)
- Display of progressive development of skills and knowledge (Robley, Whittle, Murdoch and Eaton, 2005b)
- Identification of strengths and weaknesses in key skill acquisition (Tariq et al., 2004)
- Connecting progression of learning outcomes to external criteria for purposes of quality assurance with regard to professional accreditation criteria by (Robley, Whittle, Murdoch and Eaton, 2005b; Tariq et al., 2004)
- Display of sequence of skill acquisition to students (Harden, 2001)

- Providing students with the opportunity to reflect on current state of skill acquisition and to plan future learning (Robley, Whittle, Murdoch and Eaton, 2005b).

The form and nature of curriculum mapping was dependent on the curriculum discourse. Mapping was easy with prescribed curricula but more difficult with more flexible or open curricula (Tariq et al., 2004). Reflecting on curriculum auditing for assessing aspects of employability, the UK Higher Education Academy recommended concentrating on core curricular activities to see how the pathway could enhance the learning outcomes. The Higher Education Academy acknowledged that individual course learning outcomes could be intended rather than assessed, and that some learning outcomes depended on the interrelation of course learning outcomes and on the progressive structure of a program. At the program level, the mapping exercise could address the following elements:

- Learning outcomes;
- Curriculum content or areas of expertise covered
- Student assessment
- Learning opportunities
- Learning location
- Learning resources
- Timetable
- Staff
- Curriculum management
- Students (Harden, 2001; p123).

Learning outcomes could be further broken up into expected (Harden, 2001; p123), assumed, encouraged, modelled, explicitly taught, required and evaluated learning outcomes (Sumsion & Goodfellow, 2004; p333).

While it has been suggested that curriculum mapping should " include all 'stake-holders', cover all skills, examine the whole generic skills programme for one academic year, and use a range of methodologies for the purposes of triangulation" (Robley, Whittle, Murdoch and Eaton, 2005a; p224) the review of the literature found that the mapping exercises remained predominantly in the academic realm with little involvement of industry. Student perceptions about the validity of the skills and their categorisation were likely to be different from those of the teachers (Lucas et al., 2004). Examples in the literature report

- Two reviews per course, one by the course coordinator and one by a peer review team, consisting at least of 3 faculty members with knowledge content expertise, one of the curriculum committee plus student focus groups (Britton et al., 2008)
- One quantitative survey filled out by course coordinator in combination with a qualitative interview with curriculum committee (Sumsion & Goodfellow, 2004).
- Review of documents, feedback from students and supervisors (Robley, Whittle, Murdoch and Eaton, 2005a)
- Review by module coordinator (Tariq et al., 2004)

The review of the literature found a variety of instruments used for the mapping of the curriculum at program level:

- Combination of purely quantitative survey and interviews (Sumsion & Goodfellow, 2004).
- Electronic curriculum management system (Britton et al., 2008)
- Additional Student focus groups (Britton et al., 2008)
- Document analysis, student and staff questionnaires, student focus groups, meeting with course coordinators (Robley, Whittle, Murdoch and Eaton, 2005a)
- Survey with qualitative component and additional material to clarify terms (Tariq et al., 2004)
- Real time mapping of course by teachers on electronic platform (Uchiyama & Radin, 2008)
- Open-ended surveys and interviews (Uchiyama & Radin, 2008)
- Field-notes of meetings with teaching staff (Uchiyama & Radin, 2008)
- Collective mapping by participating teachers (Uchiyama & Radin, 2008)

With regards to the skills and learning outcomes, the review of the examples revealed varying objectives:

- Mapping of skills against categories of learning outcomes (Robley, Whittle, Murdoch and Eaton, 2005a; Sumsion & Goodfellow, 2004)
- Nature, appropriateness, ability levels (proficiency) and assessment of skills (Britton et al., 2008; Tariq et al., 2004)
- Position of course within program (links to other courses) (Britton et al., 2008; Tariq et al., 2004)
- Levels of knowledge achieved (based on Bloom's taxonomy) (Britton et al., 2008)

The review found that both objective and subjective data was used for the mapping exercises.

- All course material consisting of syllabi, course objectives and learning outcomes, teaching material, assessment materials (Britton et al., 2008)
- Subjective views of course coordinators committee (Robley, Whittle, Murdoch and Eaton 2005a; Sumsion & Goodfellow, 2004; Tariq et al., 2004)

The resources available determined the nature of the inquiry:

- Limited resources: Combination of survey and interview (Sumsion & Goodfellow, 2004).
- Extensive in staff hours, tool acquisition: electronic system (Britton et al., 2008).

As curriculum design should be circular or iterative for ongoing improvement (Anderson & Rogan 2011; Britton et al., 2008; Diamond, 2008), what happens with the map is crucial for future developments. Surprisingly, the literature revealed little about the ongoing use of the maps. Above all, there seemed to be a lack of open access to the maps by existing or future students.

- Development of curriculum, administration and student performance module, password – protected access updated annually (Britton et al. 2008)
- Dynamic nature of process is stated but no evidence of ongoing or future activities in the document (Uchiyama & Radin 2008).

The review identified the following benefits and challenges of curriculum audits:

Benefits:

- Identification of revision need of course content, (Britton et al., 2008)
- Success/ gaps in alignment of courses and knowledge content, (Britton et al., 2008; Robley, Whittle, Murdoch and Eaton, 2005a)
- Identification of 'curricular streams' with sequential and related learnings and place of each individual course (Britton et al., 2008; Robley, Whittle, Murdoch and Eaton, 2005a)
- Raising of awareness of need for continuous curriculum and course revision (Britton et al., 2008)
- Provide student perception of skill acquisition (Robley, Whittle, Murdoch and Eaton, 2005a)
- Identification of additional learning outcomes (Robley, Whittle, Murdoch and Eaton, 2005a; Sumsion & Goodfellow, 2004)
- Reflection of teaching staff on teaching practice (Tariq et al., 2004)
- collaboration and collegiality (Uchiyama & Radin, 2008) ,teachers felt less isolated

Challenges

- Inertia and insecurities of staff who may feel threatened and judged (Britton et al., 2008; Sumsion & Goodfellow, 2004)
- Variation in staff interpretations of the listed skills (Sumsion & Goodfellow, 2004)
- Individual staff perceptions of the category of their learning outcomes (Sumsion & Goodfellow, 2004)
- Variations in care taken in fulfilling this exercise, (Sumsion & Goodfellow, 2004; Tariq et al. 2004)

- Difficulties by staff to judge the level of skill acquisition especially when students are provided with flexibility in assessment choice (Sumsion & Goodfellow, 2004).
- Perception of mapping process as “managerial auditing of teaching and learning” (Tariq et al., 2004, p. 79)

As a top-down approach was found to be more likely to lead to resistance among staff (Sumsion & Goodfellow 2004; Tariq et al. 2004) than the need for an audit driven by student satisfaction data (Uchiyama & Radin 2008). Strategies to overcome the reluctance by staff included

- Communication to staff of importance of collective process rather than individual assessment (Britton et al., 2008)
- Institutional support (Britton et al., 2008)
- Communication to staff of mapping as a tool to improve curriculum, teaching practice and the students’ educational experience (Tariq et al., 2004; Uchiyama & Radin, 2008)
- Communication of mapping process to staff and invitation to participation, dissemination of information material, financial reward (Uchiyama & Radin, 2008)
- Collective mapping exercise by participating teachers (Uchiyama & Radin, 2008).

Britton et al. (2008, p6) claimed that “an ongoing curriculum evaluation and mapping process involving peer review was a key component in developing and sustaining an effective professional program. If conducted in a positive and constructive way, it could alter the culture in an academic institution. By promoting the spirit of inquiry, which was the essence of academic institutions, this process allowed for an open, objective dialogue about the educational program. The process increased communication and collaborative efforts regarding instructional strategies, course content, assessment methods, and expected program outcomes among faculty members and other stakeholders. Finally, this process ensured that the curriculum reflected the goals not only of the academic institution but also of the profession, making the endpoints of the professional program visible to all involved”. However, the review found that the reality of curriculum mapping in the literature did not match this ideal vision. In only one case did curriculum mapping reportedly facilitate social capital (Uchiyama & Radin 2008, p. 273). The effects of curriculum mapping on learning outcomes have not been reported.

1.3.8 Summary

The Threshold concept holds promise as a way to frame our investigation into exploring the challenges of teaching BIM and integrating it into our curriculum. Past efforts to integrate the threshold concept into curriculum design have proven difficult. Key to our efforts are to focus on the first two questions in the Baillie et al., (2012a) Threshold Capability Integrated Theoretical Framework:

> *1. “What should the learner be capable of doing at the end, given the need to deal with an unknown future?*
>
> *2. What threshold concepts are important to understand to enable the development of such capability?*

The national Building Discipline Threshold Learning Outcomes are also instrumental to our study. All TLOs have relevance to curriculum redesign however, importantly the TLO 1 organises curriculum into four main streams including; technology, management, economics and law and TLO4 is specifically focussed on interpreting and negotiation construction information.

Clearly curriculum development processes for such a paradigm shift as we are exploring requires an iterative and inclusive process accessing perspectives from teaching staff, students and external stakeholders as well as being informed by the literature. More specifically Diamond’s (2008) two phase approach is useful to consider. Part of this will involve a curriculum audit or curriculum mapping, as well as data gathering which should address the nature of the students, the requirements and priorities of society, our industry and our institution.

1.4 Outcome 3 Student Threshold Capability Framework

This section will describe a framework that was developed based upon the threshold concept theory and integral to this is the process by which the threshold concept will be explored in relation to Threshold Capability of Building Information Modelling in the undergraduate construction management program. There are therefore two elements to the Threshold Capability, namely the content and the process to develop the understanding of what the content leading to the threshold capability is.

1.4.1 Threshold Capability Framework

We shall adopt for this study as a starting point the idea of the Threshold Capability developed by the Australian team of educators at UWA which merges knowable disciplinary threshold learning concepts with the capability theory and the need for students to be able to deal with unforeseeable future events and problems. Our review of not only the BIM educational literature but our team's research and knowledge about BIM adoption in Australia clearly establishes that the adoption is not static and thus our graduates are entering the workforce in companies that potentially have quite diverse attitudes to adoption as well as policy, process and practices that are quite varied. Our aim is to be mindful that our students will need to be able to cope with new situations and be resilient to changes and challenges. In our study to support curriculum redesign we therefore are framing our work balanced between the threshold concept theory where the disciplinary knowledge content is driving the structure of a curriculum and curriculum design based on capability theory, which focusses more on situational and progressive learning and the requirement of fundamental cognitive attitudes that are seen to be essential in becoming successful professionals. We shall be seeking to address the strained relationship between the threshold concept theory to its application to outcome-based curricula.

We need to develop an understanding of what threshold capability means in relation to teaching Building Information Modelling at RMIT. Because this is the start of the process and there is limited time and we also do not know exactly the level of BIM teaching in the program currently we shall only be addressing the following two key questions:

> *1.What should the learner be capable of doing at the end, given the need to deal with an unknown future?*
>
> *2. What threshold concepts are important to understand to enable the development of such capability?*

In the first instance we are guided by past work that identified critical points and thresholds in BIM adoption in Australian firms (London et al, 2009). We have used London et al (2009) earlier research in this area on adoption, pathways and thresholds to develop a framework so that we have a starting point for our stakeholders to respond to. The first threshold is "introductory" and is termed the 'Cognition Level' and is concerned with learning to think about BIM environments and develop basic capabilities to operate within a BIM environment as a construction manager. The next level is considered 'advanced' and is termed the ' Compatibility Level' and is concerned with learning to think, understand and act like a construction manager who integrates people, systems and processes within BIM environments, i.e. an understanding of the ability of various systems to be able to coexist harmoniously. The third level is 'application' and is termed the 'Connectivity Level' and is concerned with learning to effectively collaborate with others involved in BIM projects and demonstrate intellectual independence and autonomy to solve problems with in BIM environments. The final level is a 'self-applied' and is termed the 'Integration Level' and is concerned with learning about what it means to lead BIM projects and the organisational

environments required and how to shape the world for multiple and diverse connections. These four levels may correspond broadly to the four years of instruction in our program.

Further to this philosophical conception of these four threshold concepts of cognition, compatibility, connectivity and integration there are themes and content that a learner should be able to do which we have synthesised and distilled from the literature. We have synthesised the BIM education literature content as well as reflecting upon RMIT's strategic goals in relation to international education and identified the following key five thematic content areas:

- Fundamental principles
- Technical skills
- Construction project management skills
- Strategic organisational behaviours
- Global market context

Figure 4.1 presents the draft of a Threshold Capability for BIM in Construction project management curriculum with an initial consideration of some of the detail content topics/areas within each of the five thematic areas. At this stage we do not wish to pre-empt our consultations with our stakeholders but we also don't wish to go to our various constituents with a "blank sheet"; since there has been extensive research on this topic as well as experiences from emerging industry practice to draw upon.

The curriculum development process will be iterative and similar to Akerlind, McKenzie and Lupton (2014) we shall take a phenomenographic action research design approach which will be explained in more detail in the Section 4 Methodology.

Threshold Capability for BIM in a Construction Project Management Curriculum

Threshold concepts and capabilities are certain concepts and capabilities within a field that are required to be held to ensure mastery of a particular knowledge domain.
Threshold concepts and capabilities are transformative, troublesome, irreversible and integrative.

THEMES	**Introductory: Cognition Level**	**Advanced: Compatibility Level**	**Application: Connectivity Level**	**Integration - Self Applied: Capstones**
	Learning to think about BIM environments and develop basic capabilities to operate within a BIM environment as a construction manager.	learning to think, understand and act like a construction manager who integrates people, systems and processes within BIM environments.	Learning to effectively collaborate with others involved in BIM projects and demonstrate intellectual independence and autonomy to solve problems with in BIM environments.	Learning to lead BIM projects and organisational environments by shaping the world for multiple and diverse connections of people, organisations and systems .
	Year 1	**Year 2**	**Year 3**	**Year 4**
FUNDAMENTAL PRINCIPLES				
	Generic: Concept, Definition, Trends , Stakeholders, Implementation, Project Phases, Scope, Purpose, Conflicts	CM /QS Discipline principles application: safety, quantities, visualisation and communication, scheduling, clash detection, site planning logistics, Project Method Statements, tendering and procurement, constructability	Examples of emerging theories	
TECHNICAL SKILLS				
	Skills: Opening, Notations, Sharing, Importing, Exporting, Software: AutoCAD, Google Sketch, REVIT, Navisworks, Infraworks	Skills: Clash detection analysis, BoQ generation, Generation PMS, Proof of Concept/Re-engineering/VE, Design>Prefab, Construction sequencing, MEP trade coordination model sharing. Software: Autodesk Quantity Take off, Bentley, Solibri, VICO, Navisworks, Infraworks	Exemplars of major construction projects	
CONSTRUCTION PROJECT MANAGEMENT SKILLS				
	Simple team environments: Collaboration within the team and organisation, managing the environment	Complex collaborative environments: large scale projects or multi project contexts, leading the environment, virtual teams	Exemplars of construction organisations in networks that are highly connected (Connectivity Level) examples of entrepreneurship	
STRATEGIC ORGANISATIONAL BEHAVIOURS				
	CBA of BIM implementation, simple decision making, identification of purpose and small firm strategy, simple Model Ownership & IP rights, BIM Management Project Plans	Strategic Business Case Planning, Complex decision making, diverse strategies of Model Ownership, staff training - project start up (Level 1) , systems integration (Level 2) and knowledge management (level 3); BIM Operational Plans	Exemplars of HR training plans, global systems integration and business models of BIM implementation	
GLOBAL MARKET CONTEXT				
	Data types and management, data and information regulatory and policy framework, standards and protocols, national organisations (BuildSmart), Australian accrediting bodies standards/expectations, regional norms, values and accepted practices; beginning to understand cultural contexts and how this shapes BIM implementation	Inter-operability protocols (history of STEP/BIM/), international organisations, international accrediting bodies expectations/standards, reflexive approach to balancing the tension between local context, different ways of doing things in different countries but still operating in a multi country project team environment with various standards;	Case studies of companies that have a corporate social responsibility policy that explicitly demonstrates respect and enhancement of diversity	

final year capstone experience

"A threshold concept can be considered as akin to a portal, opening up a new and previously inaccessible way of thinking about something."

RMIT UNIVERSITY

Centre for Integrated Project Solutions

Meyer, J.H.F. and Land, R. (2003) Threshold concepts and troublesome knowledge: linkages to ways of thinking and practising, In: Rust, C. (ed.), Improving Student Learning - Theory and Practice Ten Years On. Oxford: Oxford Centre for Staff and Learning Development (OCSLD), pp 412-424.

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Figure 9 Draft Threshold Capability for BIM in Construction project management curriculum

1.5 Outcome 4 Curriculum Redesign Process for Global Co-integration

This Section outlines the methodology and the data collection and analysis methods.

1.5.1 Introduction

The learning and teaching project was originally framed in principle with a phenomenological research design, which according to O'Leary (2009) is the 'study of phenomena as they present themselves in a direct experience.' Admittedly, within phenomenological inquiry there are quite wide ranging differing definitions of its nature and tasks. Given the extraordinary philosophical roots and depth of writings on this methodology originating from Husserl in "Investigations of Logic" (1900) to contributions from his assistants and colleagues Heidegger, Scheler, Jaspers to the French contingent Sartre, Merleau- Ponty and de Beauvior and even later in Derrida's deconstruction theory –reducing it to a mere paragraph of a definition does little justice to the movement and its lengthy European tradition. According to O'Leary 'There are various forms of phenomenology including social, philosophical, existential, empirical, hermeneutical, psychological and transcendental, which are all highly theory-dependent, make it exceedingly difficult to succinctly describe its field and/or its methods." The researchers who adhere to this methodology are diverse in their interests, issues and application (Moran, 2000). There are important tenets that we can distil though.

1.5.2 Phenomenology and Phenomenography

Phenomenology is about social construction; people and their experiences are important to constructing our awareness and knowledge about certain phenomenon. Also it is inter-subjective, that is, we experience the world with and through others. Therefore a key premise is that to make sense of the phenomenon we need to see and understand it through the lived direct experiences of those who interact with the phenomenon. It is important that we suspend assumptions about causes, truth-value, reality or appearances and attempt to describe the ideas, perceptions and awareness that people have of the phenomenon. Throughout much of the writings on phenomenology one of the most important characteristics of this approach that is emphasised is that we must try to get to the truth of the matter by describing the phenomenon as it appears to the experiencer; trying to avoid misconstructions and impositions in advance. An important theme is that there should be descriptions first and that explanations should not come until the phenomenon has been understood from within (Moran, 2000).

Individuals are important in a phenomenological study but it is their experiences that are important and not necessarily the individual themselves that is the focus. Phenomenological studies are highly dependent on constructs (such as power, displacement, victory, power etc.). However similar to grounded theory the 'reality' of the construct(s) should not be imposed until the phenomenon is explored as freely as is possible. Phenomenon which are central to the study tend to sit at the intersection of people and objects and at the centre of the lived experiences of the 'objects'. The objects can be constructs and ideas or physical things but of course it is the interaction of people with the 'objects' that is central to the study. As O'Leary (2009) explains it is not what causes X, or what is X but it is the experience of X that is important. "Phenomenology is the study of the experience of the relationship between the individual and the object. It is the study of a phenomenon as it presents itself in the direct experience of an individual's direct awareness': (O'Leary, 2009 p123).

This previous discussion frames the study. We were interested in not imposing how a construction management program should be designed and delivered incorporating BIM at a detailed level and why it wasn't taught as others might be doing or as outsiders might be thinking it should be taught. We wanted to understand how 'others' are experiencing or have experienced BIM curriculum design/delivery and/or teaching and then explore to some extent how that might affect the way forward; thus reflecting upon both international experiences and our own local experiences. However there is so much background material to this phenomenon that we simply cannot be seen to ignore everything. All the researchers on this project themselves have experiences with the phenomenon in some form or another which can't be ignored. There are extraordinary detailed discussions and papers on specifics of

programs and indeed course learning outcomes that it would be inconceivable to not develop a framework – we would look ignorant. For this reason the Threshold concept was used so that we remained true to both worlds – i.e. the history of the phenomenon but also maintaining a degree of freeness from what the 'world' as it says things are supposed to be or supposed to mean prior to our working with individuals and understanding their important experiences that we can learn from.

In our world of curriculum design an important consideration is that our 'individuals' tend to form stakeholder groups including staff, current students, alumni, employers, accrediting bodies and other institutions and so dealing with the idea of celebrating the individual vs the common voice of the collective is important in this study. To this end phenomenography is a research approach that is deployed for education research that we have found useful in solving some of the issues that we have around collective meaning vs individual experience; our pre reflections on the phenomenon through the Threshold framework we developed and our ultimate aim to develop some outcomes and recommendations rather than a focus on the meanings that we may place on our empirical observations and the development and interpretation of constructs around our phenomenon. We note the evolving nature of the project and acknowledge and appreciate the sourcing of this methodology by the Project Officer.

Phenomenography is a research approach specifically "designed to answer certain questions about thinking and learning" (Marton 1986, p. 28). Based on the work of Swedish educator Marton (1986), phenomenography explores the variations in understanding of a phenomenon among different groups of people (Larsson & Holmström, 2007) and is frequently used in research in higher education (Åkerlind, McKenzie & Lupton, 2014; Entwistle, 1997). The focus of a phenomenographic approach is on the collective rather than on the individual. The aim is to convey the common experiences or perceptions of a phenomenon within a group and to compare and contrast these to the common experiences or perceptions of other groups of people in order to find categories or relationships that are linked logically and often hierarchically (Åkerlind, 2012). Categories are not preconceived but emerge from the data (Åkerlind, 2012). There are examples of the use of a phenomenographic approach in Australia including; the exploration of the understanding of academics of generic graduate attributes (Barrie, 2007) and the development of a curriculum of a two-year engineering foundation course (Åkerlind, McKenzie & Lupton, 2014; Baillie et al., 2012a).

Table 1:The differences between phenomenography and phenomenology (Barnard et al., 1999).

Phenomenography		Phenomenology	
1.	The structure and meaning of a phenomenon as experienced can be found in pre-reflective and conceptual thought.	1.	A division is claimed between pre-reflective experience and conceptual thought.
2.	The aim is to describe variation in understanding from a perspective that views ways of experiencing phenomena as closed but not finite.	2.	The aim is to clarify experiential foundations in the form of a singular essence.
3.	An emphasis on collective meaning.	3.	An emphasis on individual experience.
4.	A second-order perspective in which experience remains at the descriptive level of participants' understanding, and research is presented in a distinctive, empirical manner.	4.	A first-order perspective.
5.	Analysis leads to the identification of conceptions and outcome space.	5.	Analysis leads to the identification of meaning units.

1.5.3 Data collection and analysis methods

Qualitative data will be collected to provide in-depth information on the expectations, ideas, insights, attitudes and experiences of the key stakeholder groups of BIM education in the School of Property, Construction and Project Management (PCPM). Stakeholders who can

inform us about this phenomenon include partner universities, employers, professional accrediting bodies, teaching staff and graduates.

1.5.4 Interviews

Primary data will be collected through in-depth interviews with academic staff of RMIT and its partner universities, key employers, professional accrediting bodies and recent graduate students. For the curriculum mapping exercise documents including Program Guides and Course Guides will be collected. The interviews will be 1-1.5hrs in duration. The academic teaching staff interviews will involve focus groups as well as an individual interview with the Head of School. Six major areas will be explored with the interviewees through the following overarching questions:

1. Could you, please, start by introducing yourself?

2. Can you tell us about your current experiences with BIM?

3. Can you describe your experiences with the current level of preparation of graduates with regards to BIM?

4. Can you tell us how you see the development of BIM in an increasingly globalised construction industry?

5. We have developed a draft thresholds diagram for an undergraduate BIM curriculum, which we have sent to you. The objective was to create a holistic and BIM embedded approach. We would like to take this opportunity to discuss and reflect on this diagram.

    - Could you tell us your initial thoughts, please?

6. Before we finish, is there anything that you would like to share with us on the topics of BIM or the internationalisation of university education?

This is the basis of the interview guide for the employers. Each collective has a slightly different of questions crafted to their experiences (refer to Appendix 9.2 for the questions and the subquestions). The project involves primary data collection and interaction with humans and so according to the Australian National Human Research Ethics Conduct Code we submitted and application which was approved (refer to Appendix 9.1).

All discussions will be audio-recorded. Observational notes in a standardised Data Sheet template (refer to Appendix 9.3 for an example for interviews with employers) will be by the Research Officer and at least one of the Chief Investigators for each interview. Following each interview a debriefing exercise will take place. Compilation of all observations will be undertaken and a discussion on the key issues. The Interviewer did not take notes but was involved in the debriefing exercise. The interviewer was the Project Leader unless noted otherwise.

1.5.5 Case selection

A basic understanding of higher education construction and project management programs and some experience with BIM are essential to being able to reflect meaningfully on the subject of the inquiry. Inclusion criteria:

- connection to the undergraduate construction and project management programs as either;

    - employer of graduates,
    - representatives of employers (namely our accrediting bodies),
    - recent graduates,
    - existing partner universities and
    - staff teaching into programs

- experiences of BIM.

1.5.6 Descriptions, thematic coding and curriculum mapping

The analysis and presentation of the results of the investigation is organised in four parts:

1. Part A Empirical Observations of Stakeholder Collectives BIM Experiences
2. Part B Empirical Observations of Stakeholder Collectives' Ideas on 3 Constructs: Graduate Knowledge, Threshold Capability Model and Curriculum Internationalisation
3. Part C Curriculum Mapping
4. Part D International Institution Case Studies Internationalisation of Curriculum and Globalisation of Industry

A common synthesised data sheet with a summary of the important points as agreed in the debriefing discussion will be the first stage of the presentation of the results. Narratives and detailed descriptions shall then be developed that highlight the key themes. Part B takes these observations and describes key themes across all stakeholder collectives. Part C presents observations from the industry accrediting bodies and Part D presents a description of Auburn University's (US) approach, a University that is perhaps one of the most advanced in implementation for an undergraduate curriculum internationally.

1.6 Outcome 5 Evaluation of the Framework

The evaluation results are presented in four parts;

1. Empirical observations on BIM experiences
2. Empirical observations on 3 constructs: Graduate Knowledge, Threshold Capability Framework and Curriculum Internationalisation
3. Curriculum Mapping
4. Internationalisation of Curriculum and Globalisation of Industry

1.6.1 Part A Empirical Observations on BIM experiences

This section incorporates responses to the introductory questions in the interviews which were concerned with establishing the participant's background and their experiences with BIM education or practice for the following stakeholder collectives;

1. employer of graduates,
2. representatives of employers (namely our accrediting bodies),
3. recent graduates,
4. existing partner universities and
5. staff teaching into programs

1.6.2 Employer of Graduates

We interviewed the following employers.

Name	Role, organisation
Son Nguyen	Senior Business Analyst / Estimating Systems, Nexus Point Solutions
Adam Siegel	General Manager, National Building and Business Improvement, Metricon Homes
Daniel Kalnins	BIM Manager, Nexus Point Solutions
Industry 4	Business owner for tender management platform
Industry 5	Engineering Interface Manager
Mauricio Vargas	Mauricio Vargas, Innovation Manager, Leighton Contractors Ltd.
Steve Appleby	BIM Practice Lead for AECOM for New Zealand and Australia

Table 2 List of participants who were employers of graduates

The following is a brief narrative and description on each of these research participants in response to question 1, 2 and 3 in the interview:

1. Could you, please, start by introducing yourself?
2. Can you tell us about your current experiences with BIM?
3. Can you describe your experiences with the current level of preparation of graduates with regards to BIM?

Background

The seven interviewees from different employer organisations were working at senior and middle management levels with three of them specifically focusing on BIM implementation within their organisations. The organisations represented operate in a broad range of activities within the construction industry, including residential home constructors, commercial building contractors, civil engineering and infrastructure contractors and consultants providing architectural, design, engineering, and construction services.

Experiences

The interviewees had a variety of BIM related experiences. Some of them were fully aware of BIM and associated technology and used BIM model as consultants and as contractors on site for underground structure and above ground construction. Others have used 3D drawing tools

(SketchUP, AutoCAD) but did not have extensive BIM software experience nor construction management experience using BIM models. In a couple of organisations, neither BIM nor 3-dimensional drawings were used. Most of them have observed how BIM is utilised in the workplace and benefits of 3D visualisation and clash detection to detect problems for site safety management.

In some cases, BIM is used as a communication tool within a company to visualise the impact on sequence & time, and to attach team member responsibility to the scope of work and for change management (visual inspection - Naviswork can highlight changes for communication). In most of the cases, the BIM knowledge of participants was self-taught.

According to most of the participants, the industry is still lacking the trust and confidence in BIM models. There is a natural resistance due to a lack of understanding; some people think it is about standardisation; others such as quantity surveyors perceive it as threat and project managers do not know how the process works. Underpinning the industry is the fragmented approach to BIM adoption as BIM adoption patterns are varied. There is no consistent understanding as one quoted;

> *"I have not devoted a lot of effort to BIM. I don't know how it is going to work".*

There are also some internal challenges within the organisation with respect to change management - people don't appreciate it and do things the old way and provide a strong resistance to adoption. Some participants have seen changes in Australia during the last 12 months, but progress is still very slow. There was an idea expressed that in the US, the contractors want the models but consultants don't want to develop them, whilst in Australia it is the other way around: the consultants have been developing models for years but the contractors do not know what do to with them.

There was a perception that clients are a significant driving factor towards BIM adoption, as they know the overall picture and when they ask for BIM models then the industry responds to the demand. It is a common belief that pressure to use BIM often comes from the client and designer, and the contractor just has to fit in, and this top down pressure usually changes the industry. This is resulting in a change, albeit slow, in perception among facility managers about their role in BIM adoption. There was also discussion that clients at times demand models to be developed but were not fully aware of what they were asking for and what the purpose of the model would be after the project had completed.

Most of the participants believed that the transition is taking longer in the house building sector compared to commercial and heavy industrial sectors as BIM is not seen as a profit making activity, despite the cost of a full BIM model being only 1.2 - 1.5% of the tender cost, as mentioned by one participant. The residential sector does not automatically associate benefits with BIM;

> *"if BIM can add real benefits in efficiencies then I can see the value".*

Respondents suggested that within the Defence and Health sector (hospital buildings), clients are now asking for BIM models and that even the Productivity Commission recommends that every major infrastructure project should have BIM. Most of the participants also agreed that acceptance of BIM adoption is more likely on complex projects. Therefore, benefits in time and costs for contractors in particular are more apparent in heavy industrial projects. In building projects, monetary gains of BIM only become apparent after 3 to 4 projects. One of the participants understands that contractors could save up to 15% of cost by using BIM for conducting clash detection, visualising 4D sequence, measuring quantities, etc. By doing so, clients would be able to reduce the overall cost. But there needs to be a shared interest and identification of why BIM is needed on a particular project.

Another reason, as one interviewee suggests, for non-adoption of BIM on building projects is the "cultural difference between gas plant and building, as in building projects there is more scope and acceptance of rework."

According to the participants, there is the perception that the industry is also worried about having BIM models part of contracts. Except for in D&C and PPP projects, where contractors are involved in the contract from the early stages, the contractor has little or no influence on BIM adoption in a vast majority of projects due to them being part of a typical traditional procurement strategy or management contracting.

One of the participants in the interview sees a shift in role of quantity surveyors. Quantity surveyors could take over the new role as Project Information Managers, with responsibility of extraction of costs and quantities within projects, but also across projects, and responsible for knowledge management and analytics and not just counting the number of doors etc; The core role of QS will still be there but they need to know where they fit and how to collaborate with other team members, however there is still nervousness in this particular profession. Yet again the value proposition needs to be clear in the mind of the practitioner as the industry is quite conservative and risk averse.

"Once they [people in the industry] have gone through that journey, they never want to work 2D again."

Attitude towards/ Expectations of BIM

Expectations and attitude towards BIM, as observed during the interviews have been grouped into key thematic areas:

BIM aids **estimating:**

- BIM will transform estimating by using different quantities and accommodating simpler rates for take-off's;
- BIM will facilitate quick revision of estimates;
- Expectation of BIM to incorporate a building inventory library which is linked to costs;

Legal aspects of BIM

- BIM will become a legal document;
- BIM models will be part of contracts;

BIM aids **construction processes**

- BIM will be an opportunity for operational efficiency, to fix break downs or errors that are currently happening between sale stage - estimating - building on site.
- BIM provides opportunity for operational efficiency;

BIM aids **decision making**

- Walk through in 3D is a nice feature to have to show the client; also helps in decision making;
- BIM is empowering decision making, giving people the right information at the right time;

BIM aids construction **information management**

- BIM is used for management of information;
- BIM will include information on embodied energy in model;
- BIM is used for quality control in support of the philosophy of Right First Time;

BIM aids **client management**

- BIM is used as marketing tool, to educate customer on what the change might look like;

- BIM is about customisation;

BIM aids **Construction Work Health and Safety**

- BIM is used for planning an incident and injury free project;

BIM aids **international collaboration**

- BIM is used as a process and management tool for international collaboration as it facilitates clear communication; e.g. communication with design companies is facilitated by screen shots from model;

BIM aids **automation** and **construction production planning**

- Use of Robotics on construction site will facilitate prefabrication of components with the help of BIM; and
- Ultimately, the use of BIM will lead to construction industry becoming more like the car industry, with much reduce rework.

BIM expectations from employers is **detailed and specific on skills:**

- Industry employers have many expectations from our graduates; they want RMIT graduates to understand the basic concepts about BIM and its use within the industry.
- Expectations are that graduates should understand the value and advantages of using BIM; know current software packages, and also know the purpose of those tools.
- Knowledge about current available technology and ability:
- Skills to navigate models through Navisworks; knowledge about how different models are structured; to understand the relationship of the items in the model and know about the potential of sequencing, clashes and quantity shrinking;
- Skills to add models together; to take off basic measurements and quantities; to do sectioning of models; to set up own view points; to deal with different file formats, performance issues, import/ export of data;
- Skills to open and export from models, but **no need to be able to design in it.**

Challenges in adopting BIM

In addition to the previous expectation and attitudes, there are worries and concerns, and challenges around BIM adoption which were highlighted by the interviewees, including:

BIM **start up costs** in residential sector are daunting

- Cost of BIM models and its application in volume builder market;

Educationalists do not understand BIM as **a business proposition**

- no one is able to join the dots and academics cannot contextualise BIM for business;

Educationalists do not understand how to **change curriculum**

- Researchers do not understand how BIM will do the transition from high-tech to low-tech builders;

BIM needs a **new workforce**

- Change in work force, merging of drafting-estimating group; currently there is no link between the drawing and estimating divisions;

BIM challenges the **estimating fraternity**

- BIM is a threat to the estimating and quantity surveying industry;

BIM **value propositions** are **not well articulated**

- Convincing the industry that the advantage of BIM are in the early design/collaboration stage;

Technical difficulties with **software**

- Technical challenges with software, e.g. difficulty to see infrastructure models in Navisworks as they consist only of 3D lines (not solid shapes);

Construction project managers **resist change**

- Resistance by project managers despite showing the benefits of BIM through clash detection;

Construction **procurement** in BIM environment is **immature**

- Linking of procurement to BIM: nomenclature of model parts in heavy industrial projects is advantageous, while there is a lack of such detailed information in building construction;

Subcontractors need **upskilling**

- Use of model for facility management: in industrial projects this is mostly a safety standard (be able to shut off valve), while in buildings subcontractor would need to tag everything from the beginning;

Inexperienced workforce causes delays

- Little prior experience of workforce with BIM; struggling to find information in the model;

Clients don't **value** BIM

- Scepticism of client regarding any additional costs of BIM;

Lack of knowledge about **information requirements**

- Lack of understanding results in not asking the right questions from the design team, about the model and how designers draft them.

Interestingly the experiences indicate that the needs of the employers is not focussed so much on technical skills but a very wide range of capabilities from core construction procurement, construction planning, subcontractor management to client management, change management and business enterprise. The Threshold Capability Framework although more far reaching than most curriculum appears to be a reasonable response to the needs of the industry practitioners.

Name	**Son Nguyen**	**Adam Siegel**	**Daniel Kalnins**	**Industry 4**
Role	Senior Business Analyst / Estimating Systems, Nexus Point Solutions	General Manager, National Building and Business Improvement, Metricon Homes	BIM Manager, Nexus Point Solutions	Business owner for tender management platform
Organisation type	Offers collaboration services, such as a company tendering system;	residential building company with about 3000 homes built per year, predominantly along the East Coast of Australia	Nexus Point Solutions is a subsidiary of Leighton Holdings, an international contracting company in the infrastructure, building and mining sectors. Daniel is responsible for rolling out BIM standard within Leighton Holding with focus on infrastructure and buildings along the Australian East Coats.	Australian tender management platform, used regularly by 500 contractors/ subcontractors and suppliers. Organisation handles 75000 tenders/year; bulk of tender projects are <$10 million.
Industry perspective	Industry is still lacking the trust and confidence in BIM models	In the industry, BIM is ground zero, no great understanding; natural resistance due to a lack of understanding - people think it is about standardisation; understanding and awareness is a problem; Metricon's lean construction review of business found break down or errors and hold ups between sale stage - estimating - building on site; no real technological innovations used at the moment.	BIM is still facing resistance in the industry. Infrastructure sector is still the most difficult to convince, seemingly because those are more hand-over projects. Clients are a huge driving factor, as they know the overall picture & are supportive. Project Managers do not know how process works. Perception among facility managers is changing. Believes that transition is taking longer in building space than in heavy industrial sector as BIM is not seen as profit making; Says that all hospital clients in Australia now want BIM; also Defence, Investa, Leighton Properties	Expressed ideas about the varying adoption levels of BIM in the industry and the technical ability of stakeholders; Believes that pressure to use BIM often comes from the client and designer, and the contractor just has to fit in; His perspective on adoption of BIM by estimators: *"I have not seen a big change";* Believes that industry does not automatically associate benefits with BIM; "*if BIM can add real benefits in efficiencies then I can see the value"*; Believes that top down pressure usually changes the industry.
Attitude towards/ Expectation of BIM	BIM will transform estimating by using different quantities and accommodating simpler rates for take-off's; BIM will facilitate quick revision of estimates; BIM will become a legal document;	Sees BIM as an opportunity for operational efficiency, to fix break downs or errors that are currently happening between sale stage - estimating - building on site. Error fixing = waste of time and energy; Expects BIM to incorporate a building inventory library which is linked to costs; Walk through in 3D = nice to have, icing on the cake for the client; Says that BIM is about customisation - every job is customised; BIM is opportunity for operational efficiency; Wonders about cost of BIM and application in volume builder market - no-one is able to join the dots; academics cannot contextualise BIM for business; management of information; power of BIM is 'change' = documented; Change in work force, merging of drafting-estimating group; currently there is no link between the drawing and estimating divisions in the company. Wants to use BIM as marketing tool, to educate customer on what the change might look like; *"I want to get it into our organisation. So I am trying to find people who can help us get through that.[...] We have a desperate need. ..... we can be more efficient, ... we have customer issues, we have a desperate need that needs to be filled. And here is an answer. "*	Believes that 3D should be introduced as standard in all projects. Refers to people who are not adopting BIM as *"non-believers*" and *"non-users"*	His first impression, 7 years ago: BIM is a threat to the estimating industry; BIM looked clumsy then; he thinks that quality & collaboration would have improved since then, and that advantage of BIM may be in the early design/collaboration stage; Does not understand how BIM will do the transition from high-tech to low-tech builders; Worries that BIM may threaten his business model.

Table 3 Collated data sheet for employers of graduates Industry 1-4 - general

Name	**Son Nguyen**	**Adam Siegel**	**Daniel Kalnins**	**Industry 4**
2. … current experiences with BIM?				
BIM experience	is fully aware of BIM as he works in 'Digital Engineering Centre'; has used 3D drawing tools (SketchUP, AutoCAD2.5.1), but not real BIM software; has observed how in his workplace 3D visualisation and clash detection has helped to detect problems in site safety management	BIM knowledge of participant is self-taught. BIM is not currently used in the company, nor is 3-dimensional drawing. Has looked over the shoulders of people doing BIM	Extensive BIM experience and leading BIM knowledge in heavy industrial, infrastructure and building sectors; Responsible for rolling out of BIM across the company to get consistency and proficiency	Has only got limited direct BIM experience, when working as an estimator at least 7 years ago; Says that BIM was perceived as a threat to the quantity surveying profession then. *"I have not devoted a lot of effort to BIM. I don't know how it is going to work"*
Key quote from the interview	*"I will look at a quantity. The first thing I will say: " Can you double-check that?" All right? Because the quantity come out the model, yeah. You know, for me, it might look alright. But I need a third eye, somebody to check that. And you know to check that, the graduate will be able to drill, to go through the model and to look through that."*	*"We wanna implement, I think the plan is, to implement 3D drafting linking into estimating. Personally I see a massive opportunity to be able to take it off as we draw it. And that's potential merging of two roles at the moment. I think that, again from what I understand, 50-60% of that can happen very easily. Obviously we's be building that back into the building inventory library of items, the database, so to speak, and the rest, well, we'll have to draw and estimate. But a big chunk of the work can be automated or streamlined. "* *"I see this (BIM) as a massive opportunty in our customisation space, to do it really well."*	*"Taking a section view of a floor plate to generate a 2D floor plan helps those guys who are non-believers and non-users to get more comfortable" 33.16*	
Thoughts on BIM in international projects	currently estimation approaches differ in Australia and in the US.			

Table 4 Collated data sheet for employers of graduates Industry 1-4 – general continued

Name	**Son Nguyen**	**Adam Siegel**	**Daniel Kalnins**	**Industry 4**
Thoughts on transformation in thinking through BIM	Estimations using BIM will use different quantities than the ones used today. BIM will transform estimating by accommodating simpler rates for take-off's;	17.00 *"I think, there has to be [a shift in thinking] with BIM. We look at the silos in our business. With BIM, you almost have to clean-slate it. So ..ilf there are going to be silos, what are they, now? And then your training, it will be the same thing. So it is almost like, so we have a course now, which focusses on this non-BIM environment. Well, maybe, they will have to blend. Maybe, there is no such thing as a draughtsman anymore, we'll cal it .. something else, which means that they will have to draw in 3D and they will also be responsible for quantities. And that is called something different now. "*	Benefits in time and costs are more apparent in heavy industry projects; in buildings, monetary gains of BIM only become apparent after 3 to 4 projects. 3D visualisation is a decision making help.	
Challenges around BIM and how they were overcome			Technical challenges with software, e.g. difficulty to see infrastructure models in Navisworks as they consist only of 3D lines (not solid shapes; Infraworks was supposed to solve this but did not live up to expectations. Resistance of project managers: show the benefits of BIM through clash detection. *"Taking a section view of a floor plate to generate a 2D floor plan helps those guys who are non-believers and non-users to get more comfortable"* 33.16 Linking of procurement to BIM: nomenclature of model parts in heavy industrial projects is advantageous, while there is a lack of such detailed information in building construction; Use of model for facility management: in industrial projects this is mostly a safety standard (be able to shut off valve), while in buildings subcontractor would need to tag everything from the beginning;	

Table 5 Collated data sheet for employers of graduates Industry 1-4 – general continued

Name	Industry 5	Mauricio Vargas	Steve Appleby
Role	Engineering Interface Manager	Mauricio Vargas, Innovation Manager, Infrastructure Division - Southern Region, Leighton Contractors Ltd.	BIM Practice Lead for Aecom for New Zealand and Australia
Organisation type	Pipeline construction only package with under-ground and above-ground components		Aecom is an international company providing architectural, design, engineering, and construction services.
Industry perspective	Industry is worried about having BIM models part of contracts	Except for in D&C and PPP projects, where contractors start from zero, contractor has not influence on BIM adoption, i.e. in a typical managing contract. Cost of full COBie model = 1.2 - 1.5% of tender costs added to tender; front end loaded - design & implement model; Mismatch of needs and benefits of BIM for client and contractors: contractors' benefit: 8-15% of not having to abortive work, conduct clash detection, visualise 4D sequence, measure quantities - client wants to cut contractor's costs by 10% = client wants contractor to take the risk; There needs to be a shared interest and identification identify why BIM is needed; Internal challenge: Change management - people don't see it, do it the old way; Best measure of quality assurance: rather than having 3 different drawings on site/ office server, but there will be only 1 drawing on the robotics station on site; Recommendation: *"don't buy a printer"*; people will find a way to adjust when you mandate things;	At Aecom, BIM is called T+IMS = Technology & Information Management Solutions Group; Aecom has Design Centre in India that does drafting; they have regular discussion, so that India know what Australia expects, re codes and standards; They use genuine BIM and not just 3D models; use Aecom's own library and Aecom's naming conventions; Has seen great change in Australia during the last 12 months, but progress is very slow; While in the US, the contractors want the models but consultants don't want to do it, in Australia it is the other way around: the consultants have been doing it for years but the contractors do not know what do to with it; Residential: huge value for smaller projects, e.g. Case Study Wellington City Council, Social Housing Model, Revit model tied to asset management system, $1500 per house, they are now developing web interface; Recommendation 12.5 of Productivity Commission: every major infrastructure project should have BIM
Attitude towards/ Expectation of BIM	Believes that in 5 years' time, BIM models will be part of contracts; BIM is used for quality control in support of the philosophy of *Right First Time*; rework is not acceptable, because of incredibly high costs; instead, more time is spent by building the model in planning and for proper planning for an incident and injury free project. BIM is trusted and used to procure & construct off BIM model; He talks about *'saturation on site'*, i.e. Navisworks is used by everyone;	Personal opinion: *"I tend to believe BIM is more supplier than market driven"*; Believes that, ultimately, the use of BIM will lead to construction industry becoming more like the car industry, to reduce rework; Robotics on construction site will facilitate prefabrication of components with the help of BIM, produce less waste, facilitate 3D printing; Would like to include information on embodied energy in model ; *"We all become decoders & assemblers"*; Present attitude of building industry perceives as "*built a bit and assemble a bit with mindset of error";* Change in attitude within the discipline is needed, less acceptance and little tolerance for error and getting rid of complacency and wish to reduce waste; His vision: 3D printing acceptance , BIM no longer bricks and mortar, but be more organic;	*"This is what the crux of BIM is all about. It is empowering decision making, giving people the right information at the right time"*
Attitude towards BIM education			Quantity surveyors should be trained in BIM;

Table 6 Collated data sheet for employers of graduates - Industry 5-7 – general

Name	Industry 5	Mauricio Vargas	Steve Appleby
BIM experience	Extensive experience; is responsible for BIM model on site for underground structure and above ground construction; While BIM is not part of the contract and drawings are received in 2D: BIM is used as a communication tool within his company to visualise the impact on sequence & time, to attach responsibility of teams to the scope of works and for change management (visual inspection - Naviswork can highlight changes for communication); Prior BIM experience as an external consultant for 3D modelling/ 2D software, 12D and AutoCAD software plus attributes, quantities of earth works off 12D model Has also got experience in brownfield rail environment, integrated 3D model for clash detection, giving a naming convention, management integrated information;	At previous companies, he started projects in which BIM was explored or even fully documented	Has sophisticated knowledge of how to use BIM and acts as an advisor for several organisations; He is leader of specialist BOM advisory practice within Aecom for clients to help them understand what BIM is about and with transition; Founder member and Vice-Chair of Collaborate ANZ, a not for profit organisation , a collection of Tier 1 consultants and contractors, whose aim it is to bring industry together to share and disseminate best practice. They have 4 working groups (BIM management plans, BIM execution plans, LED's, interoperability, contract and legal aspects); they support initiatives like BuildSmart etc. Also sits on National Guidelines working group of Build Smart (to be released in November) Also sits on NZ Government Productivity Partnership BIM Acceleration Committee NZ, published the NZ BIM Handbook; Represented RICS and AIQS on this research project.
Key quote from the interview			*" We have to equip PM's especially, and QS's on how they talk that language"*
Thoughts on BIM in international projects	BIM is seen as a process and management tool for international collaboration as it facilitates clear communication: communication with design companies in Asia is facilitated by screen shots from model -*"a picture is more powerful than words";* also: use plain English only when communicating with overseas partners;		
Thoughts on transformation in thinking through BIM	Acceptance of BIM in this project through the realisation of complexity of the project. BIM view possible via mobility tablets, i.e. tablets on site; Adoption by necessity, but realisation that *"it is not so bad";* Believes that there are "cultural difference between gas plant and building", as in buildings there is more scope and acceptance of rework.		Sees shift in role of quantity surveyors: Quantity surveyors will take over the new role as Project Information Managers, with responsibility of extraction of costs and quantities within projects, but also across projects, and responsible for knowledge management and analytics; core role of QS will still be there but they need to know where they fit and how to collaborate with other team members; *" we have to equip PM's especially, and QS's on how they talk that language"* (architect will say 'why do you want that model and what do you want to do with it?'), how to manage the process; *"I see the future of BIM management as a PM function"* 27.11 *"Once they [people in the industry] have gone through that journey, they never want to work 2D again."*
Challenges around BIM and how they were overcome	Little prior experience of workforce with BIM: he runs weekly training sessions for everyone (on-site and office employees) Where to find information in the model: use of selection tree; Scepticism of client re additional costs of BIM: they convinced client that they could measure and track progress with Navisworks ID's and invoice on that;		QS' have to ask the right questions from the design team; give element codes to designer to put into model; (architects want part of fee for it = gap btw. what QS wants out of the model and how designers draft); 'Project Information Manager' = new profession in UK = perfect for QS's; "*made for a QS*" shift in role of QS: core role: not counting of door etc.; still core of extraction of cost and quantity; plus knowledge management or analytics team which sits within that QS group;

Table 7 Collated data sheet for employers of graduates - Industry 5-7 – general continued

1.6.3 Accrediting Bodies

We interviewed the following accreditation bodies.

Accreditation body	Name, Role
Chartered Institute of Building (CIOB)	Professor David Philp, Chair of the Chartered Institute of Building (CIOB) BIM working group
Royal Institution of Chartered Surveyors (RICS); Australian Institute of Quantity Surveyors (AIQS)	Steve Appleby, BIM Practice Lead AECOM,
Australian Institute of Building (AIB)	Dr Ron Webber, AIB National Vice President

Table 8 List of accreditation bodies and their representative

The following is a brief narrative and description on each of these research participants in response to question 1, 2 and 3 in the interview:

1. Could you, please, start by introducing yourself and the accreditation body?
2. Can you tell us about your current experiences with BIM and your approach towards BIM?
3. Can you describe your experiences with the current level of preparation of graduates with regards to BIM?

Australian Institute of Building (AIB)

AIB accredits the RMIT undergraduate degree. BIM is part of discussion at AIB and not part of accreditation as yet. AIB represents industry and according to our AIB representative industry asks who would pay for BIM? He also noted that there is need for a study on savings on maintenance and the cost of a BIM model

> *"They don't fully understand it; you only start to understand it, once you use it; from a historical perspective, they see the usefulness, but ultimately the owners will pay for it because of its FM application."*

The representative from AIB suggested that BIM is on the horizon, but perceived that it is not immediately usable, however AIB is looking into it. Unless industry says they want BIM, there will be little demand.

> *"BIM is on the horizon, but not immediately usable; industry is complaining about people not having enough technical skills now'*
>
> *Universities provide a broad construction management and project management degrees. If the organisation is looking for staff to become BIM proficient they can specifically trained that person up to take on that role.*

Interestingly the AIB representative said that although the industry do not want BIM proficiency yet "BIM is on the horizon, but not immediately usable"; and that industry is complaining about people not having enough technical skills now.

With regards to education the AIB representative had some interesting observations to make including;

I would like to see a more technical UG degree and then have BIM specialisation more in Masters of CM, when people have some experience;

The problem is that industry has this silly phrase where they think everybody is going to come out 'work ready'. Universities provide a broad construction management, project management type degree. It would be good if the professional body picked up the specific training for that. So, if your wanted somebody to become BIM proficient in your organisation with the computerisation, then you would train that person up to take on than role

But then there will be a mad scramble; I see the possibility of AIB and AIQS to work with industry and university to fill these gaps, e.g. unis could do a taster, tell students how BIM systems work efficiently. Then later one, they could do the training. You can't teach all the applications [at university]."

I see that BIM seems to be in early stages of development in undergraduate courses;

Some unis teach BIM as single subject & research on BIM, some do not have BIM at all, some are trying to introduce BIM across subjects & in capstone subject;

I admit a personal bias:

You need theoretical understanding before starting computerisation process and application; e.g. structures - codes coefficients, etc. source needs to be known (Australian Standards), and should not be hidden in computer package;

I think that the divide between academics & practitioners needs to be closed; practitioners need day to day proficiency needs;

Academics think they know everything but only have specialised knowledge; requirement of ongoing development of graduate;

Royal Institute of Chartered Surveyors (RICS)

In the UK, RICS has BIM Manager Certification programme; led by Salford University. BIM is a post graduate core competency for professional membership (i.e. learn BIM within 2 years after university).

BIM is only in CPD, not in undergraduate course accreditation (zero strategy for UG courses)

Both AIQS and RICS have focussed on BIM qualification in postgraduate training;

AIQS has run CostX training for their members as CPD events;

Australian Institute of Quantity Surveyors (AIQS)

Similar to RICS, AIQS have run CostX training for members as CPD events in Australia and are exploring on post-graduation pathway. They will be focussing on BIM for Project Managers

Chartered Institute of Building (CIOB)

The CIOB representative explained that BIM is not included in accreditation criteria as yet. CIOB is waiting to see the response from UKAS (United Kingdom Accreditation Service). CIOB is getting ready and has set up a working group. In UK explicit requirement of BIM Level 2 by 2016 has helped to start the conversation.

With regards to education the following observations were made;

> *Another piece that we're just finalising is we've created an education and training framework in the UK; it was a British Standard, so it's actually out for consultation at this moment in time. We've had a draft out…, it's been over a year. We've got an organisation a group called the BIM Academic Forum in the UK…*

The CIOB representative had a very wide perspective of the education of construction managers and held quite strong views regarding broadening the education of University students. He held the belief that focussing on technical skills in relation to software was not the best way forward and that thinking how BIM relates to core construction management processes and professional skills and capabilities was critical.

> *You need to not focus on technology. I would be so disappointed if I came into a university programme, universities should not train construction managers to become CAD technicians or a BIM technician. I want to come out as a project manager, a construction manager, and I'm thinking, "Wait a minute, I'm going to be employing people I'm not going to be drafting a model. I should not create a model." And I think that's the first thing. If I'm a contractor I should not be doing Revit. I will have a design team, I'll be coordinating-,*

More broadly the CIOB representative was quite focussed on the information management aspect of BIM.

> *I see three BIM value propositions:*
>
> *1) computer readable data for digital procurement process*
>
> *2) information to inform decision-making process (fit into site, affordability, energy requirements, as validated data)*
>
> *3) information for asset managers;*
>
> *I think that 90% of problems with BIM are due to poor design management;*

Accreditation body	Chartered Institute of Building (CIOB)	Royal Institution of Chartered Surveyors (RICS); Australian Institute of Quantity Surveyors (AIQS)	Australian Institute of Building (AIB)
Name	Professor David Philp	Steve Appleby	Dr Ron Webber
Role	Chair of the Chartered Institute of Building (CIOB) BIM working group; also: on the CIOB Policy Board Chair of BIM working group at CIOB Head of BIM task Group (for the past 3 years) Head of BIM at Mace Chair of BIM2050 Professor at Glasgow Caledonian University and Visiting Professor at Middlesex University	BIM Practice Lead Aecom, represents AIQS on the Standards Australia BD104 (Building Information Modelling) Working Group; was nominated by both RICS and AIQS to speak on their behalf; also: Founder member and Vice-Chair of Collaborate ANZ; Sits on National Guidelines working group of Build Smart; Sits on NZ Government Productivity Partnership BIM Acceleration Committee NZ;	AIB National Vice President; AIB accredits 13 programs in Australia,and 4-6 overseas incl. South Africa; No of graduates vary from year to year.
Industry perspective	Tier 1 contractors have already adopted the approach; is a change in culture; Tier 2 contractors are going through the program;		Says that BIM is part of discussion at AIB; AIB is driven by industry; industry asks who will pay for BIM?; *"They don't fully understand it; you only start to understand it, once you use it; from a historical perspective, they see the usefulness, but ultimately the owners will pay for it because of its FM application."*;
Attitude towards BIM/ Expectation of BIM	Sees three BIM value proposition: 1) computer readable data for digital procurement process 2) information to inform decision-making process (fit into site, affordability, energy requirements, as validated data) 3) information for asset managers; Says that 90% of problems with BIM are due to poor design management; --> role of "information manager", not "building ... "		Says that there is a need for a study on savings on maintenance and the cost of a BIM model
aware of BIM for how long, Why	UK has mandate for BIM by 2016; Personally involved in many BIM initiatives;	Personally involved in many BIM initiatives;	Has no own experience with BIM; is just keeping abreast of research
How is BIM already included in criteria?	BIM not included in accreditation criteria, yet. Are waiting to see where UKAS (United Kingdom Accreditation Service) is going; CIOB is getting ready and has set up a working group.	Both AIQS and RICS have focussed on BIM qualification in postgraduate training; AIQS has run CostX training for their members as CPD events; RICS in the UK has BIM Manager Certification; led by Salford Uni; BIM is postgraduate core competency for professional membership, with members learning BIM within 2 years after uni;	
Transformation in thinking of members through BIM	Early contractor engagement is key, as is early supply chain involvement;		
Challenges around integration of BIM and how they were overcome	1) in UK explicit requirement of BIM Level 2 by 2016 has helped to form a conversation 2) BIM means different things to different people in Australia 2) Education achievement standard BIM set up by BIM Academic Forum;		

Table 9 Collated data sheet for accreditation bodies - general

Accreditation body	Chartered Institute of Building (CIOB)	Royal Institution of Chartered Surveyors (RICS); Australian Institute of Quantity Surveyors (AIQS)	Australian Institute of Building (AIB)
Name	Professor David Philp	Steve Appleby	Dr Ron Webber
Attitude towards BIM education	*I'll just mention a few things , from my trips across to Australia, and we speak to quite a few people in Australia. Number one is BIM in Australia seems to mean many different things to many different people; it depends what lens you're looking through a perspective, you know, a client's interpretation of BIM in Australia seems quite different to the contractor's. So we were finding we were having the conversations, it's completely different conversations. I think one of the things we've been quite good at in the UK is put the maturity together, and we've been saying Level 2 BIM by 2016, and Level 2 BIM is very explicit in terms of what it's made up of, where it fits within a scope of service or fits within a contract. And I think that's really helped us about a really well informed conversation.* *Another piece that we're just finalising is we've created an education and training framework in the UK; it was a British Standard, so it's actually out for consultation at this moment in time. We've had a draft out for probably about the last, it's been over a year. We've got an organisation a group called the BIM Academic Forum in the UK…* *Undergraduate is pretty poor. What we're seeing is at undergraduate level there'll be a module on digital technology such as Revit or Bentley at some point, usually about Year 2, Year 3. Some of the more surveying classes are starting to become quite good at it and actually inject the Level 2 documentation into, it's not an explicit BIM one, but starting to inject it into what the courses are. So academia, good in terms of postgraduate, needs a lot of work in terms of undergraduate* *You need to not focus on technology. I would be so disappointed if I came into a university programme, universities should not train construction managers to become CAD technicians or a BIM technician. I want to come out as a project manager, a construction manager, and I'm thinking, "Wait a minute, I'm going to be employing people I'm not going to be drafting a model. I should not create a model." And I think that's the first thing. If I'm a contractor I should not be doing Revit. I will have a design team, I'll be coordinating-,*		Says that the industry do not want BIM proficiency yet; "*BIM is on the horizon, but not immediately usable*"; Says that industry is complaining about people not having enough technical skills now; He would like to see a more technical UG degree and then have BIM specialisation more in Masters of CM, when people have some experience; *"The problem is that industry has this silly phrase where they think everybody is going to come out 'work ready'. Universities provide a broad construction management, project management type degree. It would be good if the professional body picked up the specific training for that. So, if your wanted somebody to become BIM proficient in your organisation with the computerisation, then you would train that person up to take on than role "* Thinks that until industry says they want BIM, there will be little demand; But then there will be a mad scramble; Sees possibility of AIB and AIQS to work with industry and university to fill these gaps, e.g. unis could do a taster, tell students how BIM systems work efficiently. Then later one, they could do the training. *"You can't teach all the applications [at university]."* *Sees* BIM seems to be in early stages of development in undergraduate courses; Some unis teach BIM as single subject & research on BIM, some do not have BIM at all, some are trying to introduce BIM across subjects & in capstone subject; Admits *"Personal bias*:" "*You need theoretical understanding before starting computerisation process and & application";* e.g. structures -codes coefficients, etc. source needs to be known (Australian Standards), and should not be hidden in computer package; e.g. high end packages use - warns that is students do not have a sound knowledge of how it works, then it will be "*garbage in, garbage out*" "*If I was to start off a new undergraduate degree I would look at .. having that nice balance of here is the theory, and now do some application. So at least they get a taster of the computerisation process.*" Says that the divide between academics & practitioners needs to be closed; practitioners need day to say proficiency needs; academics think they know everything but only have specialised knowledge; requirement of ongoing development of graduate; At University of Western Sydney: there is a general discussion on BIM, but they have not moved forward; only have very limited 3D application. He is writing a paper on a clean curriculum, looks at curriculum theory; his paper will be on meeting needs of industry today but prepare students for tomorrow;

Table 10 Collated data sheet for accreditation bodies - general continued 1

Accreditation body	Chartered Institute of Building (CIOB)	Royal Institution of Chartered Surveyors (RICS); Australian Institute of Quantity Surveyors (AIQS)	Australian Institute of Building (AIB)
Name	Professor David Philp	Steve Appleby	Dr Ron Webber
How is BIM already included in criteria?	BIM not included in accreditation criteria, yet. Are waiting to see where UKAS (United Kingdom Accreditation Service) is going; CIOB is getting ready and has set up a working group.	Both AIQS and RICS have focussed on BIM qualification in postgraduate training; AIQS has run CostX training for their members as CPD events; RICS in the UK has BIM Manager Certification; led by Salford Uni; BIM is postgraduate core competency for professional membership, with members learning BIM within 2 years after uni;	
Transformation in thinking of members through BIM	Early contractor engagement is key, as is early supply chain involvement;		
Challenges around integration of BIM and how they were overcome	1) in UK explicit requirement of BIM Level 2 by 2016 has helped to form a conversation 2) BIM means different things to different people in Australia 2) Education achievement standard BIM set up by BIM Academic Forum;		

Table 11 Collated data sheet for accreditation bodies - general continued 2

Attitude towards/ Expectations concerning BIM education

Expectations and attitude towards BIM, as observed during the interviews have been grouped into key thematic areas:

BIM capabilities NOT in accreditation processes yet

- Industry accreditation bodies' general stance is that they represent industry and industry is not ready yet for BIM implementation and so they have not had increased focus in BIM capabilities in their accreditation frameworks.

Varying definitions of BIM hinders **adoption, standardisation and education**

- BIM is increasingly being adopted in the international construction industry
- Internationally there is no common understanding of BIM. The development of an ISO standard may help achieve some common understanding.
- Observation that Australian industry does not have common understanding and is lagging the world in understanding

BIM **value propositions** should be well articulated

- BIM aids **client management** for contractors
- BIM aids construction **information management**
- BIM aids the client and facilities management
- BIM aids **decision making**

BIM Threshold Capability Framework is **useful tool**

- There was a general agreement that participants found the Threshold diagram very useful as a tool underpinning BIM curriculum in an undergraduate construction management program.
- The focus on "Strategic Organizational Behaviours" and "Global Market" also received positive feedback. A suggestion was however made to introduce these aspects in the curriculum in later years (3rd and 4th).

Challenges in adopting BIM in Education

In addition to the previous expectation and attitudes, there are worries and concerns, and challenges around BIM education which were highlighted by the interviewees, including:

BIM Education is evolving and BIM needs a **new workforce**

- BIM education has focussed on postgraduate degrees
- BIM education in undergraduate should provide background
- BIM education in undergraduate should not distract from core construction methodology skills and construction management skills
- BIM education specialisation required through CPD and/or postgraduate degrees
- BIM is being considered post graduate capability and where an organization need some with BIM proficiency they can specifically train that person to take that role. Many industry organization are offering such specialist courses.
- Universities and Professional associations should work together in BIM education

BIM is emerging as a **competitive advantage** for leading education institutions in US

- US industry is ready to employ BIM capable students and this is driving US universities to have increased focus on BIM curriculum at undergrad level.
- The start-up salaries for the graduate students with BIM capabilities are generally higher than graduate with no or little BIM capabilities.
- The development of BIM curriculum may take 3-4 years.

- The biggest challenge is the upskilling of staff in BIM and to develop BIM related contents.

Australian graduates may become disadvantaged

- As the construction industry around the globe starts to implement BIM, Australian students looking to find employment offshore will be highly disadvantaged if they are not trained in BIM.

Opportunities of BIM for quantity surveyors

Quantity surveying is a major constituent of most undergraduate construction management programmes in Australia. Interviewees were asked about the opportunities for BIM in relation to the education of quantity surveying. Regarding this, an interviewee who oversees the estimating and tendering systems of his company expressed that the quantity surveying profession in Australia is still lacking trust and confidence in applying BIM in their practice.

> *"Estimations (measurements) generated by BIM present different figures than the same prepared by the National Standard of Building Measurements".*

Indeed, the measurements conducted manually by the quantity surveyors are an integrated process which not only taken the quantities of the materials into account but how the particular works are priced by the suppliers and the contractors. If we consider measurement of pipework as an example. If the measurement is completed using a BIM, the system can certainly measure accurately the net lengths of the pipework and the numbers of different shapes of junctions needed for connecting them. It is noted that based on the National Standard of Measurement, the length of the pipework should be measured in an 'extra-over' manner that also includes the overlapping lengths between the pipes and the junctions. The manual way of measuring the pipework indeed matches with the way the contractors order the proprietary products from the suppliers. A BIM has the capability of producing schedules of quantities automatically. This may suggest that measurement can be done faster than manual measurement without human errors. However, the quantities produced from an accurate BIM may make no practical sense for the contractors when placing precise orders of materials or proprietary products from the suppliers because BIM in its current form doesn't have any feature that can take various material purchasing practices and cultures of various building trades into account.

> *"Quantity surveyors are fully aware of BIM and they have used similar tools like Sketchup and AutoCAD to assist their work….." However, when it comes down to use BIM for measurement, most quantity surveyors hesitate and always "double check" the work done by BIM to ensure that the quantities came out making technical sense. However, the interviewer admitted that BIM may transform the estimation practice of the quantity surveyors and make the current complicated measurement practice simpler. It is noted that BIM may be advocated as an effective tool for use in building cost estimation in the U.S. But the interviewee stated that the estimation approach being used in the U.S. is very different from the Australia. Quantity surveying simply isn't a recognised professional in the U.S. that earns as much respect as in the commonwealth countries and jurisdictions.*

However, another interviewee, who is the BIM practice leader of an international architectural design, engineering and construction consultant company, presented different views on this topic.

> *He believed that BIM would enable "the quantity surveyors to take over the new role as a Project Information Manager, with a responsibility of extraction of costs and quantities within the project, but also across the projects, and responsible for knowledge management and analytics."*
>
> *"we have to equip PM's especially and QS's on how they talk that language…QS have to ask the right questions from the design team; give element codes to designer to put into model".*

This perspective matches with the concerns for many quantity surveyors that BIM has been heavily used and promoted in the design stream, but it has yet to be developed in a way to genuinely serve other stakeholders of the construction industry. If BIM is to be further developed as an advanced tool for all construction professionals, it has a long way to go to match operating practices of the non-designers' professionals.

The same interviewee, as a representative of the Australian Institute of Quantity Surveyors and the Royal Institute of Chartered Surveyors mentioned that the major professional bodies of quantity surveying are working hard to encourage a wider use of BIM in the stream.

> *"Both AIQS and RICS have focussed on BIM qualification in postgraduate training. AIQS has run CostX training for their members in CPD events; RICS in the UK has BIM manager Certification…"*

It is encouraging to see that the major professional bodies of quantity surveying are trying to introduce BIM to their members. This can be viewed as the professional bodies' intention to embrace BIM in the quantity surveying services. Quantity surveyors work closely with the designers. If BIM is going to be a popular tool used by the architects and the engineers, quantity surveyors are required to learn BIM as a common language among the professionals. However, it is still questionable whether BIM is developed as a tool that really addresses the need of the quantity surveyors.

1.6.4 Recent graduates

We interviewed the following recent graduates.

Name	Role, organisation
Graduate 1	Graduate of 2013; Product manager at tender management platform
Dan Collins	Graduate of 2011; Assistant Development Manager, Mirvac
Graduate 3	Graduate of 2012; Quality engineer in off-site manufacturing
Jing Yiing Chung	Graduate of 2013; Worked as a quantity surveyor until recently

Table 12 List of recent graduates

The following is a brief narrative and description on each of these research participants in response to question 1, 2 and 3 in the interview:

1. Could you, please, start by introducing yourself?
2. We would like to learn more about how you have learnt BIM
3. Can you tell us about your learning experiences with BIM?

The four graduates, who took part in the research, had a range of experiences regarding BIM. They all graduated in last three years from RMIT University, Construction Management Undergraduate Program. The current roles of these graduates include working as product manager of a technology platform; assistant development manager, quality engineer and junior quantity surveyor. Three of them have been working within the residential construction sector, and one within the commercial arena. Since, most of them have come from the residential sector, their feedback regarding industry perception was very similar; 'no talk about BIM'. They talked about the resistance within the industry and confusion regarding the uptake of BIM. From the clients point of view, BIM is 'nice to have' on their projects but they also range from either have no awareness about BIM to wanting to have BIM on their projects.

With regards to their educational experiences, graduates tended to agree that the more focus during their studies was on gaining technical skills and somewhat less focus on understanding the wider business strategy for using BIM, the way BIM is integrated into construction management core skills, information management and subcontractor management. Some key observations include:

At University I got some familiarisation with the BIM concept and a little technical hands-on skills were taught: At Queensland University of Technology, during 1st year, BIM was mentioned as concept, no examples but we thought one day it will change our life

At RMIT (from 2nd year onwards), there was more talk of BIM; I had heard that RMIT offered Revit design during 1st Year; Final year at RMIT: Google sketch-up was taught, but I felt I had missed something earlier on"

Theoretical knowledge on BIM mostly self-directed through Paul Wilkinson's blog on BIM best practice in UK (http://www.extranetevolution.com) to answer queries from boss and clients;

Other graduates had similar limited experiences:

I had only heard about BIM at university; My first real experience with BIM was during an internship in Sweden, where 3D drawings were used on site;

I don't have any technical skills in BIM, though; the uni course I did in Sweden did not have a BIM component;

I did a BIM related research project in final year at uni which was a very positive experience as I saw it in terms of onsite construction management and workflow;

I had an introduction to BIM at RMIT in construction management classes, 4D time and 5D cost scheduling, but no hands on experience;

I learnt Revit through TAFE course; some AutoCAD knowledge, but have never played with extensions, e.g. fire services

I learnt Revit in 1st year: just basic introduction for 6 weeks;

I had some exposure to Build Soft (take quantities off imported pdf drawings; measure area - take cost per unit - determine costs; as class was too big to ask questions, I learnt it through You Tube videos; Lecturers at uni sometimes mentioned BIM, but not much detail was given

In my opinion, quantity surveyors should at least understand the basics of BIM to be able to communicate with architects who have a BIM model; I believe that BIM benefits are a 3D model, cost and time savings and would deliver more sustainable buildings

Shortcoming of learning in undergraduate course (Year 3&4, CPD2): as it was a group work project, I only learnt part of the software, not the whole software (Sketch Up & Build Soft)

Revit not used again after university;

The graduates had some exposure to BIM through using Revit and so had awareness of how to create a model. In general they were in agreement that their education with regards to BIM was minimal and that there was much more that they could have been exposed to.

Name	Graduate 1	Graduate 2 - Dan Collins	Graduate 3	Graduate 4 - Jing Yiing Chung
Role	Product manager at tender management platform; Graduated six months previously (end 2013); Work experience predominantly as estimator;	Assistant Development Manager, Mirvac; Graduated 3 years previously (end 2011) responsible for feasibility and leasing of commercial buildings;	Works as a quality engineer in prefabrication, identifying defects in prefabricated modules. Graduated 2012;	Worked as a quantity surveyor until recently; Graduated in construction management in 2013; Comes from Malaysia, came to Australia after High School;
Organisation type	Online tender management platform with 8 employees, servicing the Australian market, for commercial building tenders only	Residential volume builder listed on stock exchange; Company is involved in construction, sales and marketing of properties.	Tier 2 builder that produces modular construction units, ranging from bathrooms to whole apartments; Units sold nationally and exported, too;	Quantity surveying company works for medium and small builders; involved with small - medium sized, low rise residential projects; worked there after graduation for 6 months;
Industry perspective	Says that only larger clients and designers want BIM: *"if client wants it he is going to get it"*; Survey of 70 of his company's most valuable clients said on BIM that it was *"nice to have"*; frequent response on phone survey was *"what is BIM?"*	Sees resistance toward BIM in the Australian industry; Thinks that adoption is led by Tier 1 consultants, then taken up by subcontractors and facility managers; Thinks that quantity surveyors are protecting their positions	Company thinks that BIM is confusing; external companies do not ask for BIM models	There was no talk of BIM in the quantity surveyor's office
Attitude towards BIM	Motivation for increased knowledge of BIM through current role as an in-house consultant for how construction processes work in real life; Says that *"press one button and get a bill of quantities has always fascinated me, ... but never in my life have I seen it"*;	Did not feel challenged by BIM as he was familiar with the 3D environment through computer games; Would like to have BIM model to hand over to asset management division aspiration; 3D drawings are easy to comprehend; *"I cannot see the day when you will press a button and out comes the price to build your building. The guys are good but we need to train them to understand how it can empower them.*" Thinks that Australian industry is far behind;	Would like to have BIM would be good to track the data of quality issues; believes that BIM would enable company to deal with design issues early on; critical to have knowledge of BIM (employees from car industry) Thinks that BIM is still in its infancy in the Australian industry; thinks that for modular construction hybrid knowledge is needed;	In her opinion, quantity surveyors should at least understand the basics of BIM to be able to communicate with architects who have a BIM model Believes that BIM benefits are a 3D model, cost and time saving and would deliver more sustainable buildings
Attitude towards BIM education	*"BIM is the future", "teaching for the future"* Education is needed, as there is not a lot tech-savviness among builders and contractors;	*"[The experience with 3D drawings in Sweden} really made me hate 2D drawings when I came back to Australia"*	Believes that BIM is important, but that there are not many positions for graduates in the current industry as only Tier 1 companies use it; Believes that graduates should know what tools are "*out there*", how to use them and to keep abreast of the skills; Hopes that BIM will become more mainstream by the time RMIT has curriculum;	*"I would prefer learning more software like BIM";* She sometimes asks friends about new softwares;

Table 13 Collated data sheet for recent graduates - general

Name	Graduate 1	Graduate 2 - Dan Collins	Graduate 3	Graduate 4 - Jing Yiing Chung
2. … own learning experiences with BIM?				
Learning organisation & BIM skills & knowledge learnt	University: familiarisation with BIM concept and a little technical hands-on skills taught: At Queensland University of Technology, during 1st year, BIM mentioned as concept, no examples but *"we thought one day it will change our life";* At RMIT (from 2nd year onwards), there was more talk of BIM; He had heard that RMIT offered Revit design during 1st Year; Final year at RMIT: Google sketch-up was taught, but *"I felt I had missed something earlier on"* Theoretical knowledge on BIM mostly self-directed through Paul Wilkinson's blog on BIM best practice in UK (http://www.extranetevolution.com) to answer queries from boss and clients; *"Most of my learning about industry and real life process has been through working along-side study"*	Had only heard about BIM at university; First real experience with BIM was during an internship in Sweden internship, where 3D drawings were used on site; Does not have any technical skills in BIM, though; The uni course he did on Sweden did not have a BIM component; Did BIM related research project in final year at uni which was a very positive experience as he saw it onsite construction management and workflow;	Introduction to BIM at RMIT in construction management classes, 4D time and 5D cost scheduling, but no hands on experience; Learnt Revit through TAFE course; some AutoCAD knowledge, but has *"never played*' with extensions, e.g. fire services	Learnt Revit in 1st year: just basic introduction for 6 weeks; Sketch Up used in group project: she drew one floor of the model of the QV building in 3D and duplicated it; someone else looked for sun path; Also had some exposure to Build Soft (take quantities off imported pdf drawings; measure area - take cost per unit - determine costs); as class was too big to ask questions, she learnt it through You Tube videos; Lecturers at uni sometimes mentioned BIM, bit not much detail was given
Advantages/disadvantages				Shortcoming of her learning in undergraduate course (Year 3&4, CPD2): as it was a group work project, he only learnt part of the software, not the whole software (Sketch Up & Build Soft)
Application in workplace	Never really used BIM in workplace;	BIM used to some degree in the company, mostly for 3D renderings to support sales and marketing; Mirvac - own & operate;	No application of BIM in workplace	Revit not used again after university; In quantity surveyor's offices, no application of BIM; work was based on 2D drawings.
How it is taught/ Why		Learnt in Sweden through participation in real project		
Modes of delivery		Learnt on site in Sweden and through research project		
Resources are available				
Assessments				Revit course- submission of drawing

Table 14 Collated data sheet for recent graduates – experiences with learning BIM

1.6.5 Existing partner universities and international educators

We interviewed the following international educator.

International educators	
Salman Azhar	Associate Professor and Graduate Program Chair, McWhorter School of Building Science, Auburn University

Table 15 List of international educator

The following is a brief narrative and description of the discussion by the research participant in response to question 1,2 and 3 in the interview:

- Could you, please, start by introducing yourself and your school?
- We would like to learn more about how you are using BIM in your school to educate students. Can you tell us about your current teaching experiences with BIM?
- Could you please reflect on the development of teaching of BIM in your school and describe your experiences?

Auburn University

Auburn University efforts in teaching BIM in its undergraduate and postgraduate programs started in 2009. The US industry is ready to absorb BIM proficient graduates and this has helped shaped the program. BIM has enhanced quality of teaching by using 3D models which are much better than 2D drawings.

The university discussed extensively the stand-alone teaching of BIM versus an integrated approach and ran focus groups with industry and made the choice of an integrated approach that is now being proven to be very successful.

> *We have a BIM Advisory Committee which is 15 industry people; they tell us about problems and ideas for research; industry in the US is ahead of knowledge;*

The development of BIM curriculum may take 3-4 years. The BIM curriculum is 70% technology and software skills and 30% fundamental process of BIM.

> *Every student should have some knowledge of BIM; for those students, who want to know more, there is a BIM elective;*
>
> *Students with BIM knowledge get jobs easier and are offered higher salaries*

The challenge in curriculum is to build relevant case studies and how to integrate these across different courses. The university is now venturing into the area of Virtual Reality using Ocular Rift: 3D which is virtual reality headgear to create cost-effective 3D environment. They are relatively cheap to buy but the challenge is to build the scenarios and BIM related games.

Staff capabilities was an important consideration for Auburn University and staff have varying capabilities:

> *BIM experts: 3 staff members*

Intermediate level: 3-4 staff members Cursory knowledge: rest of staff; they can discuss examples, but are not experts in the software;

We have provided Professional Development: training to staff since 2008, for e.g. we invite instructors to teach for 3-4 days for 3-4 staff, e.g. on BIM based applications; before: students who had work experience were teaching staff

My recommendation based upon my experiences is that you should get IT staff to be trained, too; this will help with resolving technical issues

The focus of the curriculum content is on technical skills. The following is a summary of the extensive integration of BIM throughout the program. There is minimal discussion on BIM as it relates to managing projects and businesses, procurement, legal aspects of ownership and contractual issues and working within teams and design management.

Year 1 &2 (pre-professional program = students with architectural, engineering and construction interest): concept of BIM and case studies: case studies - what is BIM, virtual design, virtual construction, can walk through; 3-4 hours of basic knowledge on BIM;

BSCI 2300 Materials & Methods: how simulation in BIM are constructed;

BSCI 220 Construction Communication: plan reading skills; students have problems with understanding 2d drawings; now students are provided with both 2D drawings and 3D models to visualise in 3D, see the concept of spaces and electrical services

Year 3 (professional program):

BSCI 3500 Construction Technology Information: AutoCAD, BIM;

BSCI 3420 Structures for Builders II: at the end, students construct a steel or wood structure in BIM;

BSCI 3700 Construction Safety: pick a project and develop BIM model to identify hazards, where to put crane, OHS requirements, materials, assembly area, ambulance access, excavation plans;

BSCI 3650 Project Controls: quantity surveying; use of traditional methods and some exercises using BIM.

Year 4 Project Controls III : labs; clash detection; scheduling

Name	Salman Azhar, McWhorter School of Building Science, Auburn University
Teaching role	Associate Professor and Graduate Program Chair; Has been teaching Building Science program at Auburn since 2006 Researches on BIM and teaches undergraduate, graduate and online course on BIM since 2008;
Characteristics of school	A - Undergraduate program: 100-130 students/ year; B - Post-graduate: a) Building construction (career change program) 20 students; b) Integrated Design & Construct (students with arch. And construction background with min. 3 years' experience in industry; work as a team in studio-based teaching with industry on Design & Build project); c) Online graduate program for US military (US military personnel only, as army has different procedures and procurement; 80% same content, 20% army relevant, e.g. heavy civil construction) C - Continuing education short courses for private organisations in Middle East and Africa, e.g. Egypt, Thailand
Industry perspective	Most construction companies in US are using BIM; residential companies moving to BIM; in 2-3 years, 100% of companies will be using BIM
Attitude towards/ Expectation of BIM	Some years ago, a survey the university conducted of construction companies showed that there were different kinds of jobs with different BIM requirements; e.g. BIM coordinator: little knowledge of BIM - do not have to do the model development; e.g. BIM managers - need to have some knowledge of model development and how to coordinate it.
Attitude towards BIM education	*"Every student should have some knowledge of BIM"*; for those students, who want to know more, there is a BIM elective; Students with BIM knowledge get jobs easier and are offered higher salaries; 2009: start of curriculum improvement: discussion of stand-alone versus integrated approach; ran focus groups with industry; outcome: by 2011, every student must have some knowledge of BIM; uni made the choice for integrated approach; This turned out to be the right decision; most companies are using BIM; clients don't understand 2D drawings; residential company uses ocular rift on 3D model of house; - BIM enhances quality of teaching; 3D models better than 2D drawings; every year increase BIM content in curriculum - have BIM Advisory Committee = 15 industry people; they tell about problems and ideas for research; industry in the US is ahead of knowledge; Advises that establishment of new curriculum will take 3-4 years;

Table 16 Data sheet for international educator - general

Name	Salman Azhar, McWhorter School of Building Science, Auburn University
2. … current teaching experiences with BIM?	
BIM skills & knowledge taught	**Undergraduate:** 70% of content is technology and software skills, 30% on fundamental process of BIM; students gain knowledge in Revit, Navisworks, Synchro (4D scheduling and simulation) and cursory knowledge in VICO and Tekla structures; other technologies: Laser scanning for renovation & retrofitting projects, for incorporation into BIM model and for use in decision making; Ocular Rift (virtual reality headset) and how it can be used for construction environment & safety; Incorporation of BIM into undergraduate course: Year 1 &2 (pre-professional program = students with architectural, engineering and construction interest): concept of BIM and case studies: case studies - what is BIM, virtual design, virtual construction, can walk through; 3-4 hours of basic knowledge on BIM; BSCI 2300 Materials & Methods: how simulation in BIM are constructed; BSCI 220 Construction Communication: plan reading skills; students have problems with understanding 2d drawings; now students are provided with both 2D drawings and 3D models to visualise in 3D, see the concept of spaces and electrical services Year 3 (professional program): BSCI 3500 Construction Technology Information: AutoCAD, BIM; BSCI 3420 Structures for Builders II: at end construct a steel or wood structure in BIM; BSCI 3700 Construction Safety: pick a project and develop BIM model to identify hazards, where to put crane, OHS requirements, materials, assembly area, ambulance access, excavation plans; BSCI 3650 Project Controls: quantity surveying; use of traditional methods and some exercises using BIM. Year 4 Project Controls III : labs; clash detection; scheduling BIM elective: Advanced BIM: Revit, VICO, Flash: capped at 20 students = 1/3 of students Thesis in semester 2 in Year 4: application of knowledge to existing project a) traditional thesis with 2D drawings with only a small BIM component, e.g. structural model and to use it to explain structural loads; b) BIM thesis: building>15000 sq. feet; estimates; chosen by 15-20% of students; students have to build model themselves, do everything (safety plans, scheduling, estimating etc.) c) collaborative BIM project; working with other unis, e.g. Chinese students, to build a BIM model and use applications; irregular option; **Postgraduate:** more focus on process of BIM; theory and application, e.g. interoperability, databases, process change management; development of BIM implementation plans; Integrated Design & Construct course: BIM simulations and scenarios - these models are then used in UG courses;
Resources available	**Softwares** supplied to students free of charge: Autodesk, Revit, Navisworks, Synchro (4D scheduling and simulation; works better than Navisworks); Vico; Bentley lacked resources, but was good for civil works; Revit considered to be better; **Laptops**: supplied by students; since 2011: **BIM lab** with 24 high speed computers & 5 LCD screens (4x 70 inches, 1x88 inches with touch screen panel); teach fundamental and Advanced BIM course there; **3D virtual environment lab** = cave environment: multiple projectors show images on 3 walls; sensors track position of students who wear 3D glasses; 8-10 students max at a time; $120.000 - partly funded by construction companies; will be operational by August 2015; Aim of 3D virtual environment lab: 1) for recruiting purposes; show students that construction is attractive; 2) teaching and research purposes; **Textbooks**: Design Integration using Revit, SDC Publishers; for Advanced BIM course: AutoCAD Revit Structures; **Case studie**s for exercises: provided by university, models developed by postgraduate students; **Case studie**s from industry: with permission from owners, but only used to show; for Construction Safety course: BIM model sourced by student from architect; **Assessments:** BSCI 3700 Construction Safety: assignment = video ((incl. sound) made by student showing safety measure in animation;
3. Reflection on current teaching of BIM and description of experiences	
Impact of BIM - in the past/ now	Staff capabilities: BIM experts: 3 staff members; Intermediate level: 3-4 staff members; Cursory knowledge: rest f staff; they can discuss examples, but are not experts in the software; Professional Development: training provided to staff since 2008, e.g. invite instructors to teach for 3-4 days for 3-4 staff, e.g. on BIM based applications; before: students who had work experience were teaching staff; Recommendation: IT staff to be trained, too; this will help with resolving technical issues
Challenges/ barriers - Opportunities for teaching BIM	Start up - Build case studies; solve problem of working out how to teach BIM; Future development 1) Ocular Rift: 3D virtual reality headgear, cost-effective way of using 3d environment; 30 are to be purchased, are really cheap, but the challenge is to build the scenarios; 2) BIM games development

Table 17 Data sheet for international educator - teaching experiences with BIM

1.6.6 Staff teaching into programs

We interviewed the following RMIT staff.

Name	Role
Participant 1	Lecturer
Participant 2	Lecturer
Participant 3	Lecturer
Participant 4	Lecturer
Participant 5	Lecturer
Professor Ron Wakefield	Head of School of Property, Construction and Project Management

Table 18 List of RMIT staff

The following is a brief narrative and description on each of these research participants in response to question 1, 2 and 3 in the interview:

1. Could you, please, start by introducing yourself? We would like to learn more about how you are using BIM in your course/ -s to educate students.
2. Can you tell us about your past & current teaching experiences with BIM?
3. Could you please reflect on your current teaching of BIM and describe your experiences?

Five lecturers who are teaching in the undergraduate construction management program and the Head of School were interviewed. The interviewees generally valued BIM as essential for the construction management graduates. However, they posed different views about the industry's expectation on the graduates' knowledge in BIM. Interviewee 4 expressed that

> *"people with power don't see the value of BIM".*

Interviewee 5 based on his experience in the United Kingdom pinpointed that the use of BIM on the public sector projects will become mandatory in 2016. This may drive the need for equipping graduates with BIM related skills. Based upon experiences from leading a study tour to Dubai, one of the interviewees explained that young project managers showed enthusiasm of using BIM on projects while some older managers showed resistance.

The interviewees' attitudes towards BIM education are generally cautious and pragmatic. Interviewee 5 believes that infusing BIM in the university's courses is still in infancy. However, he asserted that BIM needs to be introduced as a concept and philosophy, not as another software or tool. Interviewee 1 was concerned about how teaching of BIM can be deployed successfully. If the courses didn't fit in, BIM may be taught no different from teaching the other software. Interviewee 2 believes that in order to make BIM education successful, a holistic approach should be taken to enable students to learn the consequences of their professional legacy. Interviewee 3 was concerned about the training that the School can offer to the teaching staff. The Head of School is convinced that BIM is promising. However, the uncertain adoption of BIM in the industry has been hampering BIM to be integrated into the undergraduate construction management program. However, he stressed that

"we should be careful that we don't throw out our learning objectives and just focus on BIM… students need to be able to focus very competently on fragmented approach that industry is currently using"

At different points of the interviews nearly all participants stressed that BIM should not be taught like a tool/ software. However, when they were asked how BIM is being taught in their classes, the following responses were recorded:

"I had previously included Revit teaching through TAFE for 6 weeks. Students did basics drawings….currently an expert comes in and show students Rivet, but they still see Revit as an advanced drafting tool".

"I had introduced BIM in a yearly capstone course by showing model and by explaining what to get out of it to big class of 170 students….in final year capstone course students can work on construction projects using any sketching software."

In this aspect, the Head of School also noted that BIM is an ad hoc part of the current curriculum.

"Students are playing around with Rivet in the First Year….in yearly capstone courses, some BIM tools are used but noting it is not integrated. In the final Capstone course, students can try out what they have learned, but there is no BIM project…" "Yet, the settings are somehow a true reflection of the situation of the industry"

Most interviewees pinpointed IT skills and resources as the major challenges for teaching BIM. They pointed out that there is a lack of IT support as BIM is not a standard software.

"Worse still, some students lack computer literacy that demotivates them to learn BIM. BIM is a platform that requires collective efforts to make it work. Unfortunately, students are task oriented and this may take time to adapt to the new way of working under BIM environment. Furthermore, there is not enough support around the production of learning tools that enhance students learning experience."

The Head of School posed similar views and agreed that due to the constraint of the university IT's infrastructure, some BIM tools cannot be adapted to the system. Some BIM development companies or agencies are willing to give free licences to the School, however, the university's IT system cannot feed them in. Consequently, the School can only invest into something that works to the IT system.

The key themes that have been identified are now presented.

The key themes arising from interviewees' General experiences and attitudes were grouped into three areas namely; influence of international experiences, holistic terminology and approach, and staff strategies:

1. International industry and government experiences were more influential than Australian (Dubai, US and UK examples)
2. More holistic term and consequently a more holistic approach should be used rather than 'Building Information Modelling' which would have greater longevity in curriculum change (for example Integrated project modelling and Information Management and Communication) – currently BIM is often perceived as a technical tool (aligned to software – for eg Revit) rather than a way of thinking about the construction management process
3. Staff are key to the success of introducing BIM education and thus a range of strategies would be needed including;
    a. technical training for staff would be required (a good example of the Head of School in another country mandated all staff take training),
    b. staff need to be able to clearly identify the value of BIM for the construction management process;
    c. staff would need time to develop their own understanding and ways to introduce BIM into the teaching, a holistic approach rather than a bolt on approach would be the ultimate preferred model and that integration of staff is needed

The key themes arising from interviewees' current direct teaching experiences were grouped into two content areas namely; technical applied skills and contextual situated learning and two delivery mode styles namely; lecturer as expert and lecturer as facilitator and expert drawn into classroom as required.

Firstly it is noted that there are different levels of BIM teaching experience. One interviewee had significant experience both here and overseas, two had a moderate level of experience and two had no experience.

1. Staff had engaged in teaching BIM from a technical applied skills perspective including such examples as the use of Revit to develop up a basic Building Information Model (hence largely an advanced drafting tool) and then as a way to cost projects through the development of objects with attributes within a model.
2. Situated contextual learning including two examples; one related to construction business operations in a second year course and the second related to outcomes from using a model in a capstone course, although this was very preliminary
3. In terms of delivery, the lecturer as expert used Google spreadsheets for students to learn how to collaborate and the lecturer as facilitator and expert drawn into classroom as required used an expert to give the students a suite of instruction classes on how to use Revit and Sketchup.

The key themes arising from the final part of the interview which focussed on Challenges/Opportunities is grouped into the overarching area of threshold capabilities and it was seen as both a barrier to BIM teaching but also as an enabler and then the challenges in relation to infrastructure.

1. Literacy Theshold concepts: The discussion was quite wide ranging about the skills of the students and that this posed an inherent fundamental challenge to beginning the conversation about BIM'. The discussion was both negative and despairing and then ultimately positive about BIM being a possible underpinning platform that could address some of these issues, however that would take time. We have grouped these skills and capabilities into what we term Threshold concepts that include computer literacy, data literacy and inquiry literacy. There are basic entry level computer skills that are not prevalent in our students as well as basic principles around data and its management. As well as this discussion which is largely skills based, there was a significant wide ranging discussion on the characteristics of the students and their whole demeanour and approach to problem solving. There was

general agreement that the majority of the students were very task oriented and lacked inquiry capabilities; that they were lacking in the ability to show initiative and to explore options in problem solving situations. BIM was discussed as a means to getting the students to see things differently and appreciate the construction management process as an intelligent management process that is underpinned by data and information. The ability to capture students imagination with BIM as a Visualisation tool and develop visual literacy was also identified by the interviewees.

2. The second key challenge was regarding infrastructure support; namely in two areas including the lack of IT support and capability at the University level and then the lack of Models that could be used as teaching tools. The challenge is that the Models that have been explored do not have complete data and so when we might try to conduct analysis or simulation and export data into other programs – the data is simply not there. These are real and practical problems that need extensive investigation if curriculum was to change and we were to lead learning and teaching in this area. There is little faith in the RMIT services and support systems in quite a few areas.

Pseudonym	**Participant 1**	**Participant 2**	**Participant 3**	**Participant 4**	**Participant 5**
Teaching role	Teaches in 1st and 2nd Year, onshore only.	Teaches sustainability in the built environment onshore and at international partner universities;	Teaches in 1st and 4th Year	Teaches yearly capstone courses both onshore/ offshore; also teaches postgraduates; taught research and sustainability in the past	In charge of undergraduate Construction Management program and Sustainable Masters program; Only recently moved from the UK to Australia; Has 27 years of mostly academic experience in overseas projects on FM contracts, quantity surveying and global construction practices;
Industry perspective		Gained knowledge on adoption of BIM during a study tour to Dubai - all projects used BIM; effectiveness was determined by how it was utilised: according to the people they talked to: when BIM is used right from the start, for financial planning, them it made sense and it was fantastic to make decisions. Perceived a generation gap: project managers (PM's) were younger and used BIM; construction managers (CM's) were older, were not used to it		Thinks that *"people with power don't see the value of BIM"*	In the UK, BIM has apparent value for construction; BIM Level 2 is mandated by 2016 for public projects; contracts promote use of BIM as an early warning systems BIM is most useful in Built and Planning Phase
Attitude towards/ Expectation of BIM	Thinks that Revit is not a real BIM tool; Does not like the term BIM; would prefer the use of "Integrated Project Modelling" - it can exist without 3D or visual model				*"In the UK, BIM is […] a way of thinking."* Would prefer the term:" Information Management & Communication"; Thinks that BIM makes people think about the long term consequences and long term performance of buildings; sees power of BIM life cycle performance and sustainability of the buildings; Sees BIM as a decision making tool; believes that BIM is most useful if used from the early phases; BIM teaches how to better manage/ communicate information;
Attitude towards BIM education	Believes that to motivate students, the focus of the teaching should be on: what do you need, how can BIM help you, how do we make it work? IFC model can provide guidance for construction management; Thought that at RMIT "BIM did not really fit in"; Was afraid that teaching would be about drawing models;	Recognises importance of BIM for students when they go into industry; Sees BIM as a tool for 3-dimensional conceptualisation, to visualise and have lived experience, which enables students to learn the consequences of their professional practice legacy; With regards to curriculum innovation, believes in a holistic rather than bolt on approach. Believes that students need to have very clear outcomes and how they will be assessed for them to see the value of BIM - *"you have to sell it";* Believes that in later program years, students are better able to differentiate between the different career paths in the industry; Sees students as change agents	Says that use of Revit teaches the basics, but that "we can't get away from 2D"; Thinks that hands on training for staff would be a good thing; an overseas university's Head of School made staff take training in this BIM; Believes that integration of staff on many courses is required; Says that staff would need time to have a better understanding of BIM models;	Staff need to be a role model and to inspire students to use BIM;	Thinks that in the UK, BIM in uni courses is still in infancy; Thinks that BIM is a concept and philosophy, and not a tool;

Table 19 Collated data sheet for RMIT staff - general

Pseudonym	**Participant 1**	**Participant 2**	**Participant 3**	**Participant 4**	**Participant 5**
Teaching	BIM teaching experience in the US more than 5 years ago: a) Taught cost estimating; a quarter of the course was dedicated to "can BIM help with cost estimating & pitfalls"; used Graphisoft Constructa, which no longer exists b) Construction Data Modelling course - taught as an elective with 10 students; BIM teaching experience in Australia: a) Introduces BIM and design communication in 1st Year; b) Talks about BIM again in Year 2 with regards to effective business operations, but less than in 1st Year.	No BIM teaching experience;	Had previously included Revit teaching through TAFE for 6 weeks; students did basic drawings; found it difficult to engage the students, who could not see the relevance of Revit in the current industry; assignment was basically a drawing; Currently an expert comes in and shows students Revit, but they still see Revit as an 'advanced drafting' tool;	Has introduced BIM in yearly capstone courses by showing model and by explaining what to get out of it to a big class of 170 students; no hand on teaching experience, though. In postgraduate course has set an assignment based on BIM 'What is the BIM driver in industry?'; In final year capstone course exercise, students can work on construction projects using any sketching software	Has not taught BIM himself;
BIM skills & knowledge taught	How to use recipes to construct elements, put that into model, and then to cost it; IFC definition, classes, attributes, data base structures; Identifier for objects: how that helps manage the supply chain				
Modes of delivery	Lectures; Uses Google Spreadsheets for students to learn how to collaborate				
Key quote from the interview	*"Stop being afraid of the software"*				Says that the threshold diagram "*should embed BIM as a way of thinking";*

Table 20 Collated data sheet for RMIT staff - current teaching experiences with BIM

Pseudonym	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
3. Reflection on current teaching of BIM and description of experiences					
Impact of BIM - in the past/ now					Reflected on BIM education at universities in the UK: "*BIM is taught like a tool, but it is a way of thinking*." Mentioned one UG program that contained one course/ module on BIM; At another university, BIM introduced has been introduced CAD modules, and then BIM integrated in all courses, e.g. quantity surveying in estimating course
Difficulties of students & how helped to overcome these	Does not want students to rely on model without them knowing how the model works;				According to his observations, students had difficulties in technical aspects of BIM, and students did not understand how BIM could be used to their benefit; problems were overcome by careful matching of project teams, with having at least one or two people with current industry experience in the team; the one person with BIM industry experience would, hopefully, bring the others to the table, nurture and mature them in their BIM thinking; full time students were generally weaker than part time students who had work place experience; Also: one on one half-hour sessions with tutors; approx. 1 tutor for 20 students for technical support; Question to guide students: How can we collect this information together & store it a) Excel sheets, b) BIM - 3D models
Challenges/ barriers - Opportunities for teaching BIM	Says that many students think that BIM is Revit, i.e. a mere 3D drawing tool; Lack of IT support as BIM is not a standard software; thinks it is too risky to use BIM software; Has experienced some lack of basic mathematical knowledge in student cohort; Says that some students lack computer skills/ literacy; Says he cannot expect students to come to class, yet there is not enough support around the production of teaching videos etc.;	Sees challenges in the students' lack of computer literacy and lack of initiative; Says that students are too task oriented;	Has observed that students find visualising 2D drawings as 3D objects difficult and thinks that 3D visualisation may help; at another university overseas, he saw students turn drawings into physical models; Says that students are task oriented and show no willingness to work something out;		In UK BIM education, only few case studies were available; hence teaching was based on videos on meetings on BIM; BIM software has of pick up all aspects, e.g. Health & safety, costs; Criticisms of students on teaching BIM in UK: lack of case studies; students wanted to know how were problems overcome by using BIM; *"How do you enthuse students into the concept?"*

Table 21 Collated data sheet for RMIT staff - reflections on BIM teaching experiences

Name	**Professor Ron Wakefield, Head of School -**
Role	Head of School of Property, Construction and Project Management since 2005
Growth/ direction of construction management program	Has 10 year plan to grow the school and to improve the teaching & research performance; Had perceived that Australian undergraduates lack education in building sciences, building services, green buildings; Sees real potential for students to develop capacity in these areas; Envisaged a move from UK's model based on quantity surveying to US' engineering based structure
School's unique selling point	High regard of graduates in the work force: "*the industry seems to be very enthusiastic about our students, especially the big end of town"*; School has integrated employment and teaching, e.g. the Employer of Choice program; Encourages research led teaching;
Industry perspective	Says that *" [architects] use cheapest tool that they can get hold of* "; Has observed that industry not moving as quickly as thought; Says that sustainability and brim related skills and momentum was lost during the Global Financial Crisis; Says that industry did not move much from 1998; *"still can't do it [BIM] in most construction projects";*
Attitude towards BIM	*"I am disappointed with where BIM is.. in both the industry and in the school";* Also expresses disappointment with software vendors and their support services: "*The tool they are providing and the support means that it [BIM] is never going to be as good as it could be"*; Says that vendors did not delivered on their promises, however "*what Dassaults Systemes is trying to do is a little bit encouraging to me*", i.e. the development of a platform independent for documents of all sources; Says that for teaching purposes, architects have to be willing to share model;
Attitude towards BIM education	Is convinced of the benefits of BIM , however is concerned about the curriculum as a whole and the uncertain adoption of BIM in the industry; Wants BIM to be integrated as a tool rather than to be driving the curriculum; *"Be careful that we don't lose our learning outcomes" "Don't talk about BOM-based teaching"; "What students know should be independent of BIM*"; sees BIM as the technology that *"underpins the program*"; "*The concept [of BIM] is a very good one. So we have to be careful that we don't throw out our learning objectives and just focus on BIM. What is what, I think, several universities that have made those declarations that you are talking about have probably done. " "students need to be able to focus very competently on fragmented approach that industry is currently using. But they also need to have the capacity that, if there is a change, because I think there will be, it is just a question of - my estimation of how long it will be has been wrong on several fronts..".* (35.15) Sees students as leaders of change, ; "*We need to be independent of the platform*", i.e. the software should not matter; Sees the prerequisite of having a working system; gives advice to the vendors: "*You need to start with an educational solution that works*" (in contrast to commercial solution) ; Thinks it will be difficult to convince students; "the p*romise of BIM will not convince students*" Want curriculum to talk about what is possible. *"We have to know what the vision of BIM in the industry, where the industry will be in 10 years' time."*
2. … past & current teaching experiences with BIM?	
Teaching	"BIM part of the curriculum is ad hoc as a reflection of the situation of the industry; "Students are playing around with Revit in First Year"; says there is not enough capacity; Says approach is "piecemeal" - Revit, Sketch-up; In yearly capstone courses, some BIM tools are used but nothing is integrated.; In final Capstone course, students can try out what they have learned, but there is no BIM project;
BIM skills & knowledge taught	Has experience of BIM teaching in the US with various tools; believes that "*you need to use it every day*";
How it is taught/ Why	Underlying philosophy of teaching is to use real buildings and real projects; believes it does not matter if the teaching is paper or BIM based;
Challenges	Perceives problems with finding a suitable software: "we need some system that works and also runs through the RMIT server/platform"; had some experience with problems with licensing of software (Bentley); raises the lack of customised cost libraries, lack of working platform for cost library, lack of structural calculations software Staff limitations: "BIM teaching would require people who use it all the time"; IT limitations: "We need blackboard that runs all the projects in that space" ; Sees procurement of a model as a challenge, as industry or professionals are not willing to give their documentation/ models; explains that it took 3 years for architects to release the model of a RMIT building to RMIT;
Opportunities	ACONEX was willing to give software to PCPM, but PCPM had nothing to feed it in; Model opportunities: Vietnam campus, SAB building - is not sure if these are just 3D or really full of BIM information; thinks that RMIT could use brand and name power to change how service providers behave; Autodesk curriculum - we can look at it, but do not seem to have a BIM solution;
General future direction	"We need a system that works", "We don't want to invest into something that won't work"

Table 22 Data sheet for Head of School - general and teaching experiences with BIM

1.6.7 Part B Analysis of Key Constructs: Graduate Knowledge, Threshold Capability and Curriculum Internationalisation

This section presents the respondents' reflections on their understanding about the current state of knowledge of BIM by the graduates; their responses to the Threshold Capability Matrix and the associated comments or insights on internationalisation of curriculum or globalisation of industry are reported.

1.6.8 Graduates BIM knowledge

Employers

According to the employer representatives who took part in the interviews, graduates are expected to understand the basic concepts of BIM and its use within the industry. The acquired BIM related skills may not necessarily be related to any specific software package. Graduates should understand the value and advantages of BIM; be able to investigate the provided model, check the quantities, capture variations during construction process, and compare it with as built by using BIM. As such, it is not about knowing a specific BIM-featured tool but knowing the purpose of using that tool.

"why do you bother with this?"

One employer believed that the university graduates are comparatively receptive and adaptive to the change of technology. However, he admitted that those who join the residential construction companies are usually certificate or diploma students, not those with a Bachelor degree.

The current challenge in the industry for many contractors is how to get started and how to strategically organise for adoption. One employer saw that BIM proficient graduates would address this problem. The BIM proficient graduates, if managed appropriately, may be able to help the company to adopt BIM.

Basic requirements would include knowledge about current available technology and technical skills including being able to:

1. navigate models through Navisworks; knowledge about how different models are structured;
2. add models together;
3. take off basic measurements and quantities;
4. do sectioning of models;
5. set up own view points;
6. deal with different file formats, performance issues, import/ export of data;
7. understand the relationship of the items in the model and know about the potential of sequencing, clashes and quantity shrinking;
8. open and export from models, but no need to be able to design in it.

All the participants agreed that graduates would not have to be too specialist in one area, but would need to understand how information flows from different parties through the design and construction process. Graduates need a basic understanding of the software such as CostX, Navisworks, Solibri, and an understanding of:

1. different file formats;
2. the difference between clash detection and coordination;
3. project team integration and collaboration;
4. what drives an architect, an engineer etc.; and
5. know about the benefits in facility management.

There were a variety of views from employers on how were their expectations being met. Since, currently BIM education is not being provided by the universities, BIM education was not being met. Training for employees came under company sponsored up-skilling programs. One of the employer representatives mentioned that 50 employees of their company in the UK are doing BIM Manager Certification programme; they are trying to do the same in Australia, either through RICS or another organisation.

In Australia, BIM adoption appears is driven by software companies which does not aid development of graduates' knowledge in terms of foundational principles and theories. Most of the interviewees agreed that although there is a perception about current graduates being "tech savvy", more fundamental and important principles were needed in the graduates. Specifically the intended purpose of Building Information Modelling needs to be known and how the models can be enhanced for more efficient construction. Students are familiar with current technology and all can use iPads, but are impatient technology wise and need deeper training in the use and management of a BIM for problem solving, collaboration and analysis of various options in relation to construction methodologies.

" we can train them pretty easy and they are also willing because"

"BIM skills help careers", and

"BIM will broaden pathways for students".

Accreditation Bodies

There is little expectation for graduates to have BIM knowledge by accrediting bodies. The expectation is that they can be trained in BIM after they have graduated if their role requires so. Industry bodies such as AIB are not providing professional courses in BIM as BIM is not mandated in Australia. However as CIOB suggests as graduates are lacking in BIM knowledge industry organisations are trying to bridge the gap by running specialist courses.

Inspiration regarding BIM within the recent graduates is coming from the benefits it could offer to the improved processes within the industry.

As one stated; 'press one button and get a bill of quantities has always fascinated me, ... but never in my life have I seen it'.

This reflects that BIM usage has a lot to offer as mentioned by graduates including tracking the quality data, dealing with design issues, etc but the adoption is at its infancy within the Australian residential sector especially. Although, the industry is behind, according to the graduate;

'BIM is the future'.

The recent graduates are tech-savvy but there are not many positions available within the industry as BIM managers. Most of the graduates also witnessed that young graduates are the most proficient in using technology including BIM within their own respective companies. One of the graduates who had opportunity to work in Sweden while studying at RMIT, loved the use of BIM within the construction industry because he was able to understand different construction processes through the model, such as pouring of concrete at -17 degree C. He stated during interview;

'[The experience with 3D drawings in Sweden] really made me hate 2D drawings when I came back to Australia'.

The level of knowledge regarding BIM also varied among the graduates who were interviewed. They all were familiar with basic BIM related software including Revit, which was taught during their program. Despite their enthusiasm about the BIM, none of them had had the opportunity to 'play' with a complete BIM model nor have any technical capabilities and skills to utilise or manage a model. A couple of graduates were keen and continued their learning by self-direction through online blogs to understand BIM better in terms of its utilisation on construction projects.

Another important reason why the recent graduates interviewed were not BIM proficient and lacked skills and knowledge is that they never really used BIM in their workplace; even in professional quantity surveying offices there was little or no application of Building Information Modelling.

International educators

Auburn university's stance is very clear which was that every student should have some knowledge of BIM. Graduates with BIM knowledge get jobs easier and are offered higher salaries. There is a market imperative for universities to educate their students in BIM because they are highly desirable in the workforce.

Name	Son Nguyen	Adam Siegel	Daniel Kalnins	Industry 4
3. Reflection on current state or future knowledge of BIM of graduates				
Expected skills & knowledge/ core competencies	Graduates should concentrate on the basic knowledge and not on specific software. Should know what BIM is, what digital modelling can be used for, know how to access the knowledge. Graduates should understand the value and advantages of BIM 1) be able to investigate the model, check the quantities 2) capture variations during construction process 3) as built. Graduates will have to use software that is used by their future employer, so that they will need to be flexible. Softwares may change in the future.	Graduates used in this residential construction company are certificate or diploma students, not university graduates; these graduates do not have idea of big picture; University graduates (bachelors) end up in commercial not residential construction field; uni provides bigger picture; BIM proficient graduates *"would help with the problem who would do it. It is more about the implementation [rather than the driving]. And it is more about people understanding where we are now, and where we need to get to, and how you do that. Cause that is a real challenge. [...] Someone saying," yeah, this is where you can go. Now I am going to help you step through from where we are now, to where we are going to take you.' There are not many people who are willing or able to do that. "*	Employment criteria: 1st: personality, motivation, determination; Re BIM: to know what options there are; workflows, how a project could be managed with BIM; Core competencies are only relevant at this spoint in time, as the industry will change with time. Basic knowledge required: 1) to navigate models through Navisworks; knowledge how models are structured which is applicable to other tools: *"Naviswork or equivalent is becoming a basic, sort of entry skill"* 2) to add models together (e.g. hydronic + fire services); 3) to take basic measurements, 4) to be able to do sectioningo f models 5) to be able to set up own view points; Core tools for CM graduate: Navisworks, Sketch Up, GIS, Solibri; Data extraction with Arch Construct & attach new data; Infraworks = nice to have. Critical skills in the workforce: how to deal with different file formats, performance issues, import/ export of data;	
How were expectation met	Currently BIM education is not driven by the universities or government but by software companies; Graduates today are open to different technologies and not afraid of new softwares.			
BIM training for employees		Company sponsored upskilling of workforce in lean construction through a diploma course		
BIM skills particularly relevant in globalised industry	*"Malaysian companies have fantastic 3D models"* due to cheap labour costs, yet, in his experience, estimating is done in Excel not with software packages		"*BIM skills help careers*".	

Table 23 Reflections on current state of BIM knowledge by graduates by employers of graduates ; Industry 1-4

Name	Industry 5	Mauricio Vargas	Steve Appleby
3. Reflection on current state or future knowledge of BIM of graduates			
Expected skills & knowledge/ core competencies	Believes that it is crucial that graduates know the purpose of the tool - *"why do you bother with this?"* Graduates should have fundamental skills of how to use Navisworks or similar software; Graduates should have understanding of the relationship of the items in the model and know about the potential of sequencing, clashes and quantity shrinking.		He has chosen a graduate recently, because he knew what IFC 2.5 was; Architectural practices want someone who can do Revit; CostX to measure dwg, pdf, dws - measure quantities, Vico, Expectations 30.01: *"I want them to know, basically, what a BIM project looks like. Some understanding of the 100 and 500, a little bit of understanding what is in a BIM execution plan, where that sits in relation to contracts, ... BS 1192, PAS 1192, they will start to become national standards,"* Graduates should not too specialist in one area, but to understand how information flows from different parties through that process; need basic understanding of the software: CostX expert would be good, Navisworks, Solibri, understanding of different file formats; difference between clash detection and coordination; project team integration and collaboration - what drives an architect, an engineer etc.; Know about the benefits in facility management, too;
How were expectation met	Perceives graduates to be "tech savvy", but intended purpose of BIM needs to be known, how the models can be enhanced for more efficient construction		all can use iPad use, impatient; technology wise - " *we can train them pretty easy*";
BIM training for employees			50 Aecom employees in UK doing BIM Manager Certification programme; they are trying to do the same in Australia, either through international RCIS or trying to find the right body here to do that;
BIM skills particularly relevant in globalised industry			

Table 24 Reflections on current state of BIM knowledge by graduates by employers of graduates ; Industry 5-7

Accreditation body	Chartered Institute of Building (CIOB)	Royal Institution of Chartered Surveyors (RICS); Australian Institute of Quantity Surveyors (AIQS)	Australian Institute of Building (AIB)
Name	Professor David Philp	Steve Appleby	Dr Ron Webber
3. Reflection on current state or future knowledge of BIM of graduates			
Expected skills & knowledge	IN the UK, mostly post-graduate BIM courses, in combination with Integrated Design; in UG, modular digital tool like Revit; starting to introduce Level 2 documentation into courses		Has little expectations of BIM skills in graduates; Thinks that the syllabus is very full already; "*You can't teach them everything*". Content is put in, "but no one takes anything out"; Academic and industry should get together and talk about that, with the professional body; *"When a graduate comes out, if you want BIM training, then here is some specialist .. it can either come from the profession or professional body or in association with the academics who are proficient with it."*
How were expectation met	As graduates are not equipped in BIM, industry organisations are bridging the gap, e.g. Mace is offering graduate training, on BIM knowledge and process; awareness sessions for new graduates about standard operating procedures;		
BIM training for members	No specific training for members offered; Training of BIM outside of academia: lots of courses are springing up, e.g. RICS BIM Manager; Mace: offers 3D course for supply chain = knowledge in process; BRE BIM Accredited Professional course; Vendors are offering software courses; people are being "*tooled up*";		AIB is not providing BIM training for members; because BIM is not mandated in Australia; "*Until that happens, it is difficult to convince the owner of the value of BIM";* Says that if 20-30 big construction companies wanted people to be trained up, then there could be a course in conjunction with the Institute
BIM skills particularly relevant in globalised industry			

Table 25 Reflections on current state of BIM knowledge by graduates by accreditation bodies

Name	Graduate 1	Graduate 2 - Dan Collins	Graduate 3	Graduate 4 - Jing Yiing Chung
3. … current experiences with BIM?				
BIM used for how long, Why; How and to what extent; Type of projects, stages	No hands on experience with BIM; has only seen outputs of BIM model of Geelong library; Boss did not want to buy CostX software to open model	Only hands on BIM experience during his work experience in Sweden		
BIM in international projects		Has observed that some international companies have a BIM Centre of Excellence	same manufacturing process in China as in Australia; via ship to AUS; labour costs lower in China higher volume over there at cheaper labour costs he is worried about quality assurance	
Transformation in thinking through BIM	Has witnessed that youngest person is often the most tech proficient person and young people are teaching older guys;	Thinks that BIM has accelerated his understanding different construction processing, for example pouring of concrete at -17^{o}C		
Challenges around BIM and how they were overcome	Lack of " tech-savviness" among builders and contractors and nature of people			

Table 26 Reflections on current experiences with BIM in the workplace by recent graduates

1.6.9 Threshold Capability Framework

Employers

The Employer group gave very rich feedback on the threshold diagram.

The first point that was emphatically made was related to problems restricting ourselves to the term BIM. The term BIM is applicable to civil infrastructure and capital procurement in the mining sectors and yet they don't use terms such as 'building'. The 'building' in BIM may imply that BIM can only be used in building works. Obviously BIM has wider applications.

Other positives observations regarding the framework was that teaching technical skills about BIM to students is good. It was noted that students would be expected to be able to:

> *1) Explain the bigger picture of BIM, knowing the "why" right at the start", for example by showing exemplars in 1st Year.*
>
> *2) Understand relationship of BIM to their careers.*
>
> *3) Provide exemplars and real world examples to articulate the concept and use of BIM.*

The other feedback from the group was that the term 'Level' may be confused with UK BIM Levels mandate (in Strategic Organisation Behaviours, Year 2): calling it 'phase' may be better since there is no accepted practice.

One participant enquired what a capstone was and in general what do they do in the Year 4 Construction Management Program? The response was in principle that in Year 4, students should be able to apply all that they have learned in the previous years in that particular course. If possible, students are expected to be mentored by some industry people.

It was also suggested that the curriculum should have a mix of modelling software, to accommodate civil engineering works.

Change management processes should be covered as a soft aspect within the curriculum. An important discussion took place in relation to the term student Resilience. It was elaborated that students should not lose sight that they have been trained in something that is powerful which may not be adopted the particular organisation that they are employed by but that there may be another time and/or place where it becomes important and not to be disillusioned by their current employer's lack of engagement, as one stated;

> *"Resilience is really important... For their first year or two year or three year or four year or five years, maybe they are just going to accept the fact that they are going to meet the organisational imperatives right now. But I am not going to lose sight of the fact that I've been trained in something that is really powerful. At some stage, I wanna see that realised. So that when I start to manage people, or I have my own business, or I am leading a business, or whatever it is, there is a world out there that can be done a whole lot better. The resilience to say 'I am just going to meet my organisational imperatives for now, I am going to do what I am told today, and tomorrow and the day after, BUT..'. Resilience is a good one".*

Participants also mentioned that students should learn about

- project planning and control,

- integrated project delivery and
- scope management; these are important for all stages of the project life cycle.

Other topics include

- change management and impact upon time and cost;
- BIM modelling work flows, and
- BIM management project plans.

On the operational side it was highlighted that setting projects up for asset management is becoming more & more important;

> *"we need to know what facility managers want from the model".*

There were suggestions for other areas that were important including;

- understanding of all stakeholders' role in creating, using and managing a BIM;
- how to sell the concept to the designer/ builder/ owner;
- integration and lean construction,
- Procurement and construction using the model and its potential use in housing.
- A need was also highlighted to look into technical aspects and collect the feedback from site onto the model, e.g. concrete shrinks and affects dimensions on site; etc.

Other areas which should be covered and which came out from the interviews include;

- site operations modelling and site logistics; i.e. what is around the building; streets, roads, energy supply,
- processes & procedures, e.g. new emerging technologies;
- materials tracking through RFID scanning and linking it to BIM & scheduling; and last but not the least
- is to understand BIM information input, e.g. libraries - how can that become more efficient?

Ideal teaching/ delivery methods

It was suggested by some participants that BIM should be taught through action learning projects which will help students with BIM transition for e.g.

> *"help craft transition, or be involved in the implementation of it, or diagnose it in a business who is thinking about it".*

It was thought that it was critical that academia and industry should collaborate so that best practice examples could be demonstrated. Students should also understand the business and enterprise aspect of the industry, as stated by one participant;

> *"It is so important to have business context. I guess that is the global market context and the strategic organisation behaviour part in the diagram. ..For our industry, in these construction project management skills, that collaboration piece is.. try to get some really powerful examples, best practice examples, that would be really useful. .. This is critical"*

In group work, sending work packages from one group to another would help students to learn how to communicate clearly. Case studies would help in walking through different stages of a project - investment planning, business case, concept stage, phase to consultant, design and construction, as well as in-use phase.

It was also noted that the RMIT SAB building has 3D design model/BIM, academics could take it and explain what is in the model and what is not, why it is not usable for QS; etc. We could use the model to explain the different things that make up a wall for example; and turn things off in a BIM model that are dumb objects that do not have properties assigned, and see how it was created in the first place.

Accreditation bodies

The representatives from the industry bodies were in general agreement about the philosophy of integrated approach to teaching BIM rather than stand-alone. One industry body representative made a comment that in order to add more content some of the other content needed to be removed and deciding what to keep and what to throw out will be very challenging. Another industry body representative made a good suggestion by explaining that first year should be team building among students from different pathways and then adopt a mode of T-shaped learning. The threshold diagram is useful and in that it aspires to the teaching of BIM as a complement to project management and construction management skills and student graduating are project and construction managers with BIM capabilities and are not BIM technicians.

Past Graduates

The response of past graduates related to the integrated model (framework) was very positive; they saw the validity of it; liked the themes and how the curriculum was broken up over the four years within each of those themes. A couple of suggestions were to start teaching basics of BIM within the ‘Communication course’ and gradually into other courses at advanced level.

There was some confusion of how to underpin the BIM concept with Global Market context in 3rd year within the framework because working in a global market is not taught anywhere now. One of the graduates strongly supported the idea of equipping graduates with strong technical skills related to BIM.

Some of the key elements that should be in the Framework and suggested by the graduates included:

- sound knowledge of how things work - high level overview, including facility management;
- understanding the benefits of BIM;
- how to combat reluctance by older and influential people and how to communicate or show them the benefits of BIM;
- the different purposes and processes of BIM during the building life cycle;
- use of BIM for the Off-site Manufacturing processes within the industry;
- confident enough to teach / demonstrate others;
- understand BIM related technical issues (with international perspective and not to be Australia specific;
- know how to design in BIM , know "how to format a wall" in Sketch-up;
- interact with other people including BIM designer during the process; and
- able to use pdf drawings (2D) and BIM (3D).

Since RMIT is a global university of technology and design, the graduates suggested that students should learn BIM as part of the program. Some optional course on advance BIM should also be offered. Students should also be given a BIM model to understand and price take-off. Also, students should also be encouraged to complete a partially designed BIM project, e.g. services lay out (sub-model). But on the other hand, it was also suggested that the graduates should also be prepared for reality:

> *"you don't want [graduates to know] BIM the only thing they use - they would be shocked [when they land within the industry]"*

International educators

A very positive response was received by the international educator who was very complimentary of the threshold diagram. There was agreement of technical skills to be included in the curriculum as proposed however a suggestion is made that Strategic Organisational Behaviours and Global Market Context should not be covered in early years. It should be best left for postgraduate studies or should be introduced in later part of undergraduate degree in year 3 and year 4.

Summary

Detailed refinement of the Threshold Capability Framework would be an ongoing process. The most significant themes shall be incorporated into the Framework. Important points to remember as well:

> *We need to understand where we teach a basic understanding of information management before we embark on any ambitious program of advanced information management technologies and capabilities*
>
> *We focus on skills approach at the moment*
>
> *We don't appear to teach anything to do with working in a globalised environment*
>
> *We have identified 5 thematic areas but we must remember and stress that this does not necessarily mean that these are 'courses' - these are simply content areas that could be taught in a range of different locations which would be refined in various future curriculum planning stages*
>
> *We need to me mindful that the Australian construction industry is not ready … Adoption patterns in the industry are so inconsistent that we need to be mindful that we have to teach for a transition period anyway … and thus the concept of Graduate Resilience is critical*
>
> *We need to negative mindsets and perceptions in the industry to contend with and develop resilience skills in our students*
>
> *We need to be aware that just as there is a lack of skills industry this is also new to quite a few in higher education and so in an implementation stage we must not lose sight of the importance of core graduate outcomes and our staffs' ability to teach core construction management courses and that infusing Construction*

Management Digital Literacy is a long term and evolving exercise and we must build confidence in delivery capability

We are the leaders in Australia and we are one of the leading institutions in the world and so we need to reflect upon our position and take a lead in some way … and if the industry is not ready should we not do anything … we have to lead somehow … we do have to lead so that our students are global ready – i.e. can step into an office or on a site not just in downtown Melbourne

Name	**Son Nguyen**	**Adam Siegel**	**Daniel Kalnins**	**Industry 4**
5. Threshold diagram discussion				
Response to Integrated Model	*"Why do you restrict yourself to BIM?"* finds the term BIM restrictive due to the word 'building'; in his workplace the term 'Digital Engineering' is used which encompasses applications in mining and infrastructure; proposed term 'City Information Modelling'	5 areas make sense, range of technical through to strategic components are perfect, important to have market context	2 guiding principles for teaching:stood out (emphasis on technical part): 1) Explaining the bigger picture of BIM, the value proposition, "*knowing the why right at the start",* for example by showing exemplars in 1st Year. 2) Decision of what is nice to have, what is critical: Revit: graduates should be able to open and export from models, but do not need to be able to design in it. Navisworks = the Basis Solibri; great but not essential; Other tools: show students what is out there;	*"Sequence makes sense"*, e.g. cognition, compatibility etc.
Topics	curriculum should mix modelling software, to accommodate civil engineering works	Change management process should be covered; Resilience: students should not lose sight that they have been trained in something that is powerful *"Resilience is really important. .. For their first year or two year or three year or four year or five years, maybe they are just going to accept the fact that they are going to meet the organisational imperatives right now. But I am not going to lose sight of the fact that I've been trained in something that is really powerful. At some stage, I wanna see that realised. So that when I start to manage people, or I have my own business, or I am leading a business, or whatever it is, there is a world out there that can be done a whole lot better. The resilience to say 'I am just going to meet my organisational imperatives for now, I am going to do what I am told today, and tomorrow and the day after, BUT..'. Resilience is a good one"* *is in strategic organisational behaviours;*	On RFI (request for information), rework, as built red line mark up - explain to students why that happen and how BIM could add value; Provide exemplars. Missing in the draft: GIS: some knowledge important, similar to knowledge on Revit and Sketch Up	Believes that students will require skills proposed to be learned in Year 3 only in 10 years' time.
Ideal teaching/ delivery methods		Action learning project - students to help with BIM transition: e.g. "help craft transition, or be involved in the implementation of it, or diagnose it in a business who is thinking about it" Collaboration - get powerful best practice example, this is critical *"It is so important to have business context. I guess that is the global market context and the strategic organisation behaviour part. .. For our industry, in these construction project management skills, that collaboration piece is.. try to get some really powerful examples, best practice examples, that would be really useful. .. This is critical"* Academics can't explain BIM in business context, *"people don't get it", "they cannot join the dots"*	Use of real world example; Explode out different workflows;	Suggests using practical examples, as they are easier to remember than something more abstract

Table 27 Reflections on thresholds capability diagram by employers of graduates; Industry 1-4

Name	Industry 5	Mauricio Vargas	Steve Appleby
5. Threshold diagram discussion			
Response to Integrated Model			Term 'Level' may be confused with UK BIM Levels mandate (Level 2 in 2016) (in Strategic Organisation Behaviours, Year 2): calling it 'phase' may be better; there is no accepted practice; Not all students will join big firms; What is capstone, what do they do in Year 4? - Year 4: apply all that they have learned in the previous years, often students team up with industry Important still to have good project and design managers
Topics	Project planning control - integrated scope is important for all stages of the project life cycle; Change management of time & cost = key things Look at BIM work flows, as there are the big benefits; BIM management project plans; On the operational side: setting project up for asset management is becoming more & more important; "we need to know what facility managers want from the model" AutoCAD Quantity Take Off tool may no longer exist Suggests more discussion of integration and lean construction: modelling BIM work flows to get it right; Topic: Procure & construct off the model and its potential of BIM in housing	Technical possibility of feedback from site onto the model, e.g. concrete shrinks and affects dimensions on site; Understanding of stakeholders; how to sell it to the designer/ builder/ owner What is the next step for BIM? E.g. site operations modelling = site logistics; what is around the building; streets, roads, energy processes & procedures, e.g. new emerging technologies; BIM = information input, e.g. libraries - how can that become more efficient? how do we make BIM more efficient and cheaper in itself? Materials tracking through RFID scanning and linking it to BIM & scheduling;	Autodesk Quantity take off does not exist anymore, gets wrapped into Navisworks in next release; "*Do not fixate too much on tools, as they will change.*"
Ideal teaching/ delivery methods	Send work packages from one uni to another to learn how to communicate clearly in a brief		Case study - walk through different stages of a project - investment planning, business case, concept stage, phase to consultant, how to share information, SAB is design intent model - take it and explain what is in the model and what not, why it is not usable for QS; Explain the eight things that make up a wall; Turn things off that are dumb objects that do not have properties assigned, see how drafters have cheated, e.g. 50mm screed as table top - comes up as concrete and falsifies quantities. Example for Naviswork model: 567 Collins Street, Investa

Table 28 Reflections on thresholds capability diagram by employers of graduates; Industry 5-7

Accreditation body	Chartered Institute of Building (CIOB)	Royal Institution of Chartered Surveyors (RICS); Australian Institute of Quantity Surveyors (AIQS)	Australian Institute of Building (AIB)
5. Threshold diagram discussion			
Response to Integrated Model	Agrees with integrated model: *"[Teaching BIM} should be definitely undergraduate level, 100% …., but infused within the courses, not as a standalone…"* First year should be team building amongst students of different pathways, then vertical stratification (cf. should be T-shaped learning); thinks that presently there is too much focus on pigeon holes, e.g. stratification of architect, engineer etc.; Praises that focus is not only on technology; says that students should be trained as project and construction managers with BIM capabilities, but that they do not need to be able to draft in BIM; managers will have CAD technicians for that;		Likes structure, seems logical to him; Says *"It is just a matter of time: what do you keep, and what do you throw out?"* Favours gradual adding of BIM to complement teaching;
Topics	Topics: 1) transition of analogue to digital construction, i.e. transformation 2) economics of construction - global, borderless 3) understanding the work stages 4) understanding client information requirements 5) information management 6) classification management 7) cyber security, big data, semantic data - global significance; in UK , demand for computer scientists and mathematicians in construction industry is emerging; Primavera P6, NavisSimulate, Synchro		Sees a problem with fitting in content: *"How much of the technology do you throw out to fit another?"* Questions maturity of students: *"Questions about all technology is that you have to understand the inputs really well; that is hard to get as a 21-22 year old."* Believes that graduates need to be employable on technical skills;
Ideal teaching/ delivery methods			

Table 29 Reflections on thresholds capability diagram by accreditation bodies

Name	Graduate 1	Graduate 2 - Dan Collins	Graduate 3	Graduate 4 - Jing Yiing Chung
5. Threshold diagram discussion				
Response to Integrated Model	Sees the validity of it; liked themes and how the curriculum was broken up;		Recommends to start with BIM in communication course;	Suggests to teach gradually, become more advanced and then master it; Suggests to not stop in 1st Year, but to continue further on;
Topics	Was confused: *"Is it the whole program or just the BIM approach?;* Kerry London: K: not a whole new degree, is a framework Did not understand Global market context 3rd year - where is BIM?	What graduates should know: 1) sound knowledge of how things work - high level overview, including facility management; 2) understanding the benefits of BIM 3) how to combat reluctance by older and influential people and how to communicate or show them the benefits of BIM 4) the different purposes and processes of BIM during the building life cycle	Technical skills - students should "*play with it*"; Students should be able to notate and understand and use functions of program rather than being able to drawing in it; Puts forward that manufacturing is not taught at uni at the moment;	
Ideal teaching/ delivery methods	Teach younger generation to be confident enough to teach others/ demonstrate; BIM technical - RMIT should not be Australia specific; Students to learn how to design in BIM , know "how to format a wall" in Sketch-up; Students to be prepared for reality: *"you don't want BIM the only thing they use - they would be shocked"*; students should be able to use pdf & BIM; Perhaps optional course on BIM - what would be the outcome? -suggests to examine student preference; Suggests to give students a BIM project and do price take-off; Give students a partially designed BIM project, e.g. services lay out = submodel; Students to learn how business work is interacting with BIM designer, i.e. the process;			

Table 30 Reflections on thresholds capability diagram by recent graduates

Name	Salman Azhar, McWhorter School of Building Science, Auburn University
5. Threshold diagram discussion	
Response to Integrated Model	Liked integrated concept of embedding BIM rather than adding BIM on;
Topics	Fundamental principles, Technical skills -seemed all fine to him; Recommendation: Strategic Organisational Behaviours and Global Market Context - should not be covered in UG level, as he feels that topic requires knowledge of business which UG students would not have; Despite Kerr explaining that RMIT has 4 years of teaching, while Auburn has only got two, and that RMIT students start work in 1st year, Salman still recommended to move it to 3rd or 4th year to be better understood and applied by the students;
Ideal teaching/ delivery methods	

Table 31 Reflections on thresholds capability diagram by international educators

Pseudonym	**Participant 1**	**Participant 2**	**Participant 3**	**Participant 4**	**Participant 5**
5. Threshold diagram discussion					
Response to Integrated Model	Thinks that if BIM came later in the curriculum, it would make it easier, as students would know the basics of data management; Staff have to teach what they are supposed to (non-BIM related content) and students have to know it; BIM too early; better: general information in 1st Year, BIM only in 2nd. 1. teach first: how to share data, security/ safety, e.g. Facebook not private; 2. prepare students, e.g. communication class, how to structure/ store data; BIM in Year 2, when we have CM students and no longer all three disciplines in one class - teach specific BIM then; e.g. Enovia of Dassault Systèmes, project information platform, how to share data	Examined the proposed threshold from the aspect of curriculum innovation: recognised that it takes a holistic approach; questioned the learning objectives, how does BIM fit in, what is the role/ purpose of BIM in the program or how does it best facilitate what students need to do - believes that only when these questions are answered, then the application becomes feasible. Warns of a crowded curriculum - says that students need to understand the value of learning BIM: WHY we are teaching it?; benefits and relevance to students need to be established first; establish benefit to students, why it is relevant to students - then it can be worked out where to teach what	Inquired about the underlying rationale of the threshold: *"Do we want to teach them as pedagogical method or just superficial management the program?"* E.g.in the pedagogical approach, courses would be integrated through databases/ BIM models		believes that threshold diagram "*should embed BIM as a way of thinking*"; Likes embedding BIM in UG program: "wonderful, not done elsewhere, BIM Sees capstone courses showing students' understanding of BIM in life project;
Topics	In 1st year: Microsoft Excel - Vlookup functions, to develop skills in querying the model rather than learning Revit;	thinks that topics should be determined by contemporary practice: what drives innovation? Thinks reflective practice is important; Asks if industry is dictating the content or if students should lead? - Thinks that there needs to be a mix of both	Suggests to teach theory in individual courses and the applications using BIM in the cap stone courses in Year 2, 3 and 4; Suggests that students shoals learn about series of time versus series of objects; Suggests learning about work-flow management on site on a daily basis	Teaching should introduce the areas but leave it to students to explore; We have BIM model - what do we do with it?. Thinks that too much representation is also counter-productive;	
Ideal teaching/ delivery methods	Suggests to give them an application and to show them how to use it; Raises the question of an appropriate software tools - *"we have to look at what industry is using now";* Suggests to share a BIM model across courses: *"We just have to get a model and share it across courses*"	Suggests the use of case study to make students sees the benefits of BIM	Suggests use of the same model across different courses in the same year		Describes ideal approach: get one student from project management, construction management and architectural studies together in one course that pulls together all you have done, work as a team; Case studies are necessary for success; show students how BIM solved problems; Positive example at a UK university: students worked with architects and contractors on a real project in an integrated studies course; prove to be effective, as problems and BIM learnings were shared; Endorses Real Learning approach: suggests local architect to come & teach a case study; expresses need for practitioners, not academic lecturers; "*students need hands on approach, bring industry into the classroom"* Suggests to pull on alumni and their experience with BIM; Recommends to connect different courses with one real project;

Table 32 Reflections on thresholds capability diagram by RMIT teaching staff

Name	**Professor Ron Wakefield, Head of School -**
5. Threshold diagram discussion	
Response to Integrated Model	Agrees in principle; Says that Year 2 content in draft is taught across Year 2 and Year 3 ; threshold contains too much in Year 2; teaching progresses from low rise to high rise buildings; Notes that some items listed for Year 3 are happening in Year 4, e.g. exemplars of emerging theory is part of Year 4; Curriculum does not contain much on facility management; believes that the most compelling benefit of BIM lies in decisions on how to manage the building; "*BIM is essential to FM";* may be incorporated in Year 2 Strategic Organisational Behaviours;
Topics	*"Skills is just one part of it"* Property course in 1st Year: understanding of BIM is important; BIM has the power to influence clients; management thinking: suggests talk about case study
Ideal teaching/ delivery methods	Suggests use of real life projects; Suggests involvement of senior people in industry, who look at the "*bigger picture*" and want the communication/ culture of learning; Stresses that "*strong technical competence is still important";* Would like to see curriculum focus on both skills (paper based and BIM); Suggests to map thresholds to classes;

Table 33 Reflections on thresholds capability diagram by Head of School

1.6.10 Globalisation of industry and Internationalisation of curriculum

Staff

Of the five academic staffs, two gave reflections on globalisation. One mentioned that it's only within the last two to three years that BIM started to appear in the curriculum of some construction management programs in other countries. As BIM was not part of the construction management program in previous years, industry practitioners usually acquired related skills through self-learning. However, the use of BIM has gained momentum in some countries where students have good IT skills including India and Hong Kong. Another participant believed that BIM knowledge will provide mobility opportunities for students and give them a competitive edge. However, the Head of School emphasise that

> *'we need to be aware that the industry does not move as quickly as we might think'.*

At College level, BIM has yet to be part of the discussions in the internationalisation of curriculum even though we have three Schools who are a significant stake in the education of graduates for the built environment.

Employers

An employed suggested that globalisation brings challenges but also opportunities. For example, Malaysia has cheaper labour that in Australia and excels in producing 3D models. A similar situation arises in Vietnam and India and are currently being used for outsourcing development of 3D and BIM models.

Because of wider use of BIM around the world including European countries, local companies use international BIM case studies to demonstrate to project managers what is BIM and how it is used. In the US, BIM is more advanced, and prefabrication is also done through BIM, and it supports any changes to adopted construction technology. In the UK, the government mandate helps in adoption of BIM but there are still several issues which need to be resolved. UK industry groups want to export standards to the Middle East; Hong Kong, NZ, Australia but all of these countries are now starting to write their own guidelines, which are albeit are fairly common. The tension between being global and working local is felt by the majority of the participants who thought that BIM would not be mandated within Australia in the near future.

The biggest challenge, as identified by most of the participants lies in how to prepare students for a slow changing industry, for the transition period before BIM becomes universally adopted. Although BIM is not accepted practice everywhere but change is occurring and in some places in Australia quite quickly (for e.g. the health sector and the industrial sector);

> *Our attitude has to be that we are fluid enough; we have to be a bit responsive to change*

Accreditation bodies

One industry body representative noted that internationally there is no common understanding of BIM. In Europe, ISO standard is in development stage and this will achieve some common understanding internationally. A local industry body representative mentioned that the lack of BIM knowledge and training will pose problems and challenges for local graduates aspiring to work in the countries internationally where BIM is mandated and they

need to realise this shortcoming and should be up skilling themselves in this area. This might also help them in securing higher salaries.

Graduate

One graduate, who is working for a tender management platform company, is helping his company to expand the market abroad into other English speaking countries due to the globalisation of the business environment. He observed the UK has a bigger push for BIM adoption compare to Australia. Another graduate had international work experience in Sweden while studying the program and he observed that some of the international companies have BIM Centres of Excellence. He observed that BIM is common practice in Sweden for people up to mid-20's.

International educators

The international educator indicated that in his university BIM facilitated construction project collaboration. He also noted that there is an active exchange between students in US, Asia (Pakistan, China), South America (Ecuador), Europe, Australia and it the introduction of BIM at undergraduate level has helped students to find jobs internationally.

Name	Son Nguyen	Adam Siegel	Daniel Kalnins	Industry 4
4. Globalisation of industry & Internationalisation of curriculum				
Challenges	Malaysia has cheap labour and excels in producing in 3D models	No international projects and primarily local suppliers, yet some drafting and estimating is done in Vietnam.	Companies use international BIM case studies to demonstrate to project managers what is coming with regards to BIM. In Norway, only 3D drawings are used -> is now cultural issue US: more advanced, prefab through BIM, changes construction technology, e.g. iron hangers are precast in the concrete UK: mandate helps with the adoption of BIM; issues: 3D model produced has to be at the end but teams are not forced to have it at the beginning Does not think that BIM will be mandated within Australia or within his company;	
Positive outcomes - added value			BIM skills help careers.	

Table34 Reflections on globalisation of industry and internationalisation of curriculum by employers of graduates; Industry 1-4

Name	Industry 5	Mauricio Vargas	Steve Appleby
4. Globalisation of industry & Internationalisation of curriculum			
Challenges		Believes that the challenge lies in how to prepare students for *'checked' world,* for the transition period before BIM becomes universally adopted.	Example of international collaboration and 24 hour working on a project for Build Sydney live as a joint project with BIM Academy; used 46 different types of software, create design for a convention centre within 48 hours. UK want to export standards to the Middle East; Hong Kong CIC, NZ, Australia are starting to write guidelines, all fairly common; *"Only issue we have had was with the UK rewriting COBie* (COBie 2012): *"we looked at it for Australia. It is good, ..., but it is just very hard to get your head around. so we sort of bastardised it for some clients here in Australia"* 35.25 ; Global perspective - BIM is not accepted practice everywhere and all changes very quickly; attitude has to be "*fluid enough; we have to be a bit responsive"*
Positive outcomes - added value	BIM will broaden pathways for students as BIM skills are necessity in civil engineering works;		

Table 35 Reflections on globalisation of industry and internationalisation of curriculum by employers of graduates; Industry 5-7

Accreditation body	Chartered Institute of Building (CIOB)	Royal Institution of Chartered Surveyors (RICS); Australian Institute of Quantity Surveyors (AIQS)	Australian Institute of Building (AIB)
4. Globalisation of industry & Internationalisation of curriculum			
Challenges	Internationally there is no common understanding of BIM; In Europe, ISO standard that is in development will be the foundation across nations;		Admits that "*our graduates would be disadvantaged overseas where BIM is mandated"; "if you don't have a good understanding of BIM, then employability is going to be comparability low"*
Positive outcomes - added value			Thinks that BIM knowledge will add value and enhance employability;. *"But there are so many outcomes for employment for construction graduates ,.. There just have huge opportunities there now,. So they may decide never to be a BIM specialist*"; "*But if I was a young graduate, I'd be seriously looking at it. Because that sort of proficiency will give you a job. And my suspicions are, it will give you a higher paid job. Particularly if you have overall very good grounding in construction*" Describes that Deakin university has double degree of architecture and construction, and that- those graduates are starting to take over the design management process.

Table 36 Reflections on globalisation of industry and internationalisation of curriculum by accreditation bodies

Name	Graduate 1	Graduate 2 - Dan Collins	Graduate 3	Graduate 4 - Jing Yiing Chung
4. Globalisation of industry & Internationalisation of curriculum				
Challenges	His tender management platform company is looking at expanding internationally into 2 English speaking countries; Biggest competitor is Aconex: international, focussed on the UK and pushing for BIM; Challenge for Australian tender management company: getting the knowledge to ship it overseas, e.g. bilingual application in US = Spanish; Aconex does it; "builders" = subcontractor in US; Language; definition of terms;	Has observed that BIM is common practice in Sweden for people up to mid-20's; Has observed that some international companies have a BIM Centre of Excellence		
Positive outcomes - added value				

Table 37 Reflections on globalisation of industry and internationalisation of curriculum by recent graduates

Name	Salman Azhar, McWhorter School of Building Science, Auburn University
4. Globalisation of industry & Internationalisation of curriculum	
Challenges	BIM facilitated project collaboration and active exchange between students in US, Asia (Pakistan, China), South America (Ecuador), Europe, Australia;
Positive outcomes - added value	It will be easier for students to find a job in US or in the Middle East with BIM knowledge; past collaboration with Pakistan, China, Ecuador;

Table 38 Reflections on globalisation of industry and internationalisation of curriculum by international educators

Pseudonym	**Participant 1**	**Participant 2**	**Participant 3**	**Participant 4**	**Participant 5**
4. Globalisation of industry & Internationalisation of curriculum					
Challenges					His perception of BIM use in Dubai: BIM used at design stage, then it fizzles out and people tend to ignore it. Thinks that this is partly true in UK, too. Thinks that Hong Kong is most innovative in use of technology; contractors specialise in BIM right from site set up to key stage of how work sequences take place; BIM use is very refined; unis started with BIM 3 years ago, but industry had to learn BIM themselves (IT skills are very good; better technical modelling, animations); India: BIM adoption is taking shape now; most hospital designs and design documentations incl. BIM for UK done in India; e.g. Delhi Airport -a) Indian unis are adopting BIM - students have more IT skills; b) Mumbai/ Delhi -> architects work on UK projects, i.e. design, documentation and BIM done by Indians; Design & Build by UK firms, but design and documentation done in India; Thinks that in India (Mumbai, South India), Hong Kong, uni students are "blessed with IT skills"; students are far more proficient in IT skills from early years than in UK;
Positive outcomes - added value		Believes that BIM knowledge will provide mobility opportunities for students and give them a competitive edge;			

Table 39 Reflections on globalisation of industry and internationalisation of curriculum by RMIT teaching staff

Name	**Professor Ron Wakefield, Head of School -**
4. Globalisation of industry & Internationalisation of curriculum	
Political insights into future of CM	At College level, BIM not part of discussion in internationalisation of curriculum
PCPM as leaders in CM higher education	
Student mobility	Yearly capstone course is taught in Singapore, Hong Kong and Australia
PCPM graduate profile	Aim: *"students need to be industry-ready*" Cautions that "*we need to be aware that the industry does not move as quickly as we might think"*

Table 40 Reflections on globalisation of industry and internationalisation of curriculum by Head of School

1.6.11 Part C Program Curriculum Map

Current Course Accreditation documents of the programs were not readily accessible thus making it difficult to map course learning outcomes, curriculum design and delivery methods as envisaged by objective 1. We had anticipated that we would be able to use the current mapping of the programs across these main elements and simply overlay the mapping of the new subject area onto the existing curriculum mapping. The School maintains several Accreditations for the three discipline areas (construction management, property and project management) which have varying accreditation requirements. The programs may be accredited for three to five years and in some case annual partnership meetings are held. The School has restructured twice in the last five years with the change of program management staff. This has posed some challenges with the maintenance of our archives of Accreditation documents. The School identified this as one of the areas of improvement in its 2014 Learning and Teaching plan and made efforts to streamline accreditation related processes. As a result of it the Accreditation register was developed and Accreditation documents were made available on common secure staff drive. However, this process consumed time and was completed during 2014 and therefore the Accreditation mapping documents were not available to us. We were not in the position to map learning course learning outcomes, curriculum design and delivery methods as envisaged by objective 1. However we did develop a visual map of the program and the courses which had not been done before and we were able to map through the interviews with staff where BIM is currently taught.

The Bachelor of Applied Science (Construction Management) (Honours) develops the theoretical knowledge and technical skills required to work effectively in construction management professional. Graduates of this program are equipped with a sound knowledge of construction management strategies, production factors and the industrial environment within local and global contexts and will be able to independently analyse industry trends, current and emerging. The School of Property, Construction and Project Management (PCPM) at RMIT University has a primarily discipline-bound curriculum. In the BH114 Bachelor of Applied Science (Construction Management) (Honours) curriculum, 91 precent of courses are prescribed.

The design of the curriculum is closely connected to the OBE (Outcome Based Education) philosophy discussed in Section 3. An outcome based curriculum is characterised by its designed structure and its focus on the learning of the student. Outcome or Competency Based Education (OBE) is characterised by the learner-centred approach and addresses individual achievements at hierarchical levels. OBE is a top-down design of the curriculum where learning outcomes drive the curriculum design. OBE curriculum designs involves constructive alignment of a tiered and comprehensive framework of learning outcomes Learning outcomes are the clear statements of what the learners would be able to. Learning outcomes are usually structured according to Bloom's taxonomy (Kennedy, 2007; Lozano, Ceulemans, Scarff & Seatter, 2014).

The National Australian Qualification Framework (AQF) defines learning outcomes for all levels of formal education and has set standards for both university wide 'graduate attribute' (or 'profiles') and for Bachelor programs. The Australian Qualifications Framework defines learning outcomes as " the expression of the set of knowledge, skills and the application of the knowledge and skills a person had acquired and was able to demonstrate as a result of learning" (Australian Qualifications Framework Council, 2013; p97). Learning outcomes can be distinguished at two levels- program level learning outcomes and course level learning outcomes. Program or degree related learning outcomes were developed to reflect the generic university graduate learning outcomes. Course learning outcomes describe what the student should learn in a particular course and how it contributes to the achievement of the year or program learning outcomes.

The following are the program learning outcomes for Bachelor of Applied Science (Construction Management) (Honours).

PLO1 Determine and apply knowledge of complex construction management theory to your professional practice and/or further study

PLO2 Professionally communicate to a range of audiences, demonstrating in depth knowledge of the discipline and of the needs of diverse construction management stakeholders

PLO3 Apply logical, critical and creative thinking to analyse, synthesise and apply theoretical knowledge, and technical skills, to formulate evidenced based solutions to industry problems or issues

PLO4 Utilise appropriate methods and techniques to design and /or execute research based or professionally focused construction management projects, demonstrating capacity for independent and collaborative learning, addressing real world industry issues

PLO5 Collaborate effectively with others and demonstrate intellectual independence and autonomy to solve problems and/or address industry issues and imperatives

PLO6 Critically examine and reflect on the profession, in local and/or global contexts, and question accepted interpretations and decision making

The AQF specified that universities had to define learning outcomes in the domains of 'people', 'fundamental', 'thinking' and 'personal skills'. The program learning outcomes cater for these learning outcomes.

The program map and the various courses are depicted in Figure 12 and are mapped according to the Australian Institute of Building knowledge domains. The first year is a common year across three undergraduate programs where students take courses from construction management, project management and property and valuation discipline. This is a deliberate curriculum design decision and provides two benefits; 1) It introduces first year students to management, technical and economic related knowledge in three discipline areas and 2) it gives students in each program a chance to know about the other programs and thus make more informed decisions about their choice of career pathway. The students are provided with the opportunity to change programs after their first year. There is an unintended consequence and that is we have observed it is also helps reduce attrition rates. Year two, three and four provide specialised knowledge in the construction management discipline. The students are gradually introduced to more challenging content such as legal and increased technical knowledge.

Year two, three and four also exhibit a distributed model of capstone courses. Rather than having one capstone course towards the end of the degree program, there is a capstone course at each year:

1 Level 2 BUIL1245 Construction Planning and Design 1
2 Level 3 BUIL1256 Construction Planning and Design 2
3 Level 4 BUIL1262 Construction Planning and Design 3.

The capstone courses are offered in semester 2 and reinforce the students' learning that happens in four courses in semester 1 in that year level. The capstone courses also incrementally build up knowledge as the year level advances and are in line with Blooms Taxonomy and requirements of Australian Qualifications Framework (AQF). Year four also provides a research experience which is a requirement of an honours program.

Figure 10 maps program learning outcome across various courses in the degree program. PLO1 relates to the technical knowledge and is achieved evenly across all year levels. PLO2 deals with developing communication skills and receives more focus in year three and year four. PLO3 relates to developing critical thinking skills and is also evenly achieved across all year levels. PLO4 involves learning research skills and these are catered for primarily in year four. PLO5 is about developing team work skills and is dealt with evenly across all year levels. PLO6 relates to understanding local and global context and has more focus in year two, three and four.

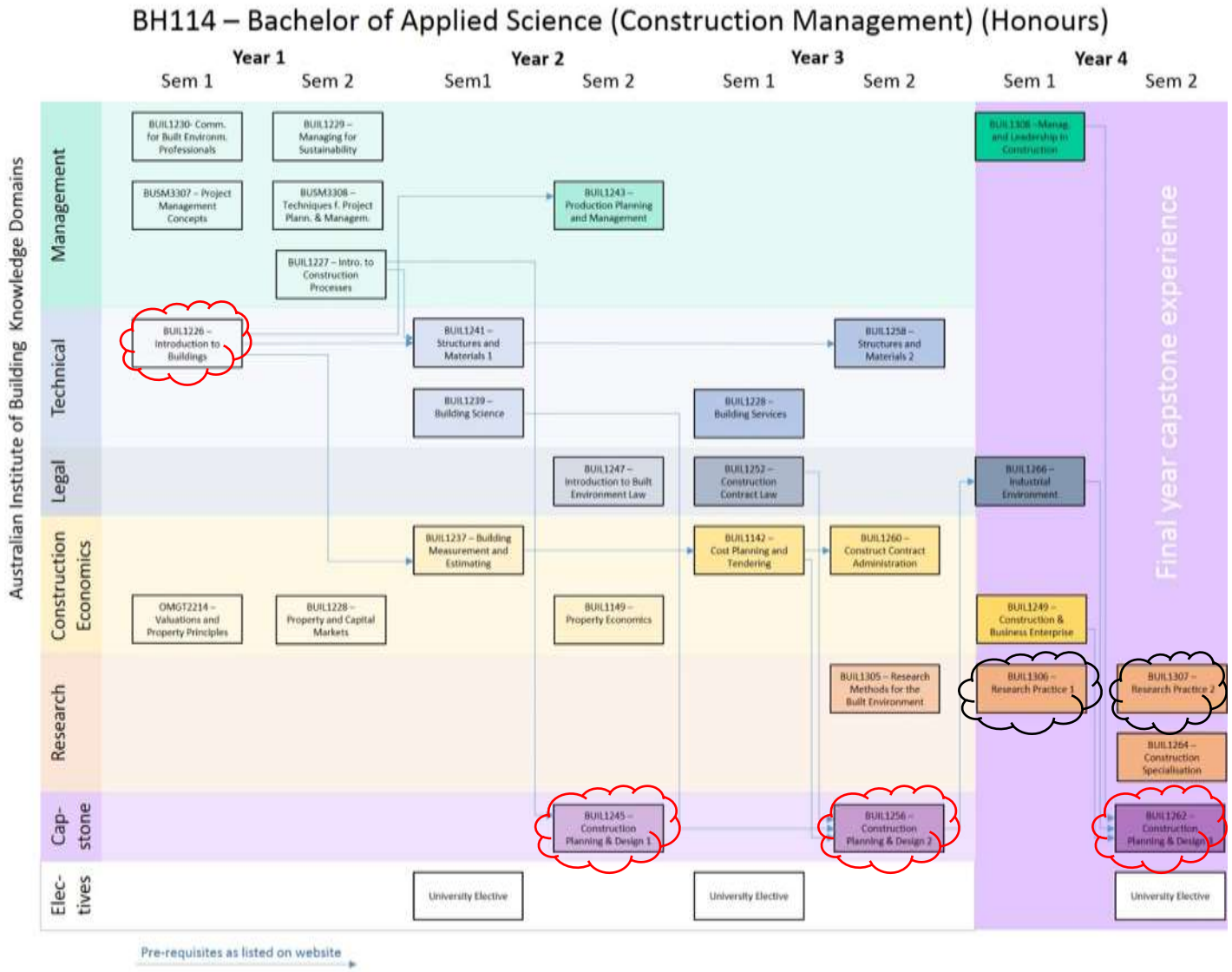


Figure 10 Curriculum map BH114

Program Learning Outcomes Matrix

Program Learning Outcomes	GA#	AQF*	Year 1 courses	Year 2	Year 3	Year 4
1. Determine and apply knowledge of complex construction mangement theory to your professional practice and/ or further study	GA1 GA2, GA3 GA4 GA5, GA6	K1, A2	BUIL 1226 OMGT 2214 BUSM 3307 BUIL 1230 BUIL 1227 BUIL 1223 BUSM 3308 BUIL 1229	BUIL 1237 BUIL 1234 BUIL 1239 BUIL 1241 BUIL 1245 BUIL 1249 BUIL 1149	BUIL 1128 BUIL 1252 BUIL 1256 BUIL 1260 BUIL 1258 BUIL 1305 BUIL 1142	BUIL 1249 BUIL 1266 BUIL 1262 BUIL 1264 BUIL 1306 BUIL 1307 BUIL 1308
2. Professionally communicate to a range of audiences demonstrating in depth knowledge of the discipline and the needs of diverse construction management stakeholders	GA1 GA2 GA3 GA5 GA6	S2, S4	OMGT 2214 BUIL 1230 BUIL 1223 BUSM 3308	BUIL 1239 BUIL 1245 BUIL 1149	BUIL 1128 BUIL 1142 BUIL 1305 BUIL 1256 BUIL 1305	BUIL 1266 BUIL 1262 BUIL 1264 BUIL 1306 BUIL 1307 BUIL 1308
3. Apply logical, critical and creative	GA 1 GA2 , GA3 GA4 GA5 GA6	S1, S2, S3, A1	BUIL 1226	BUIL 1237	BUIL 1128	BUIL 1249

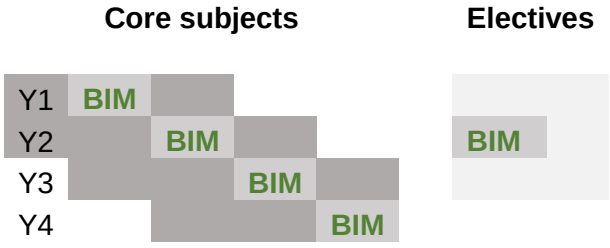
Figure 11 Program Learning Outcomes

The previous section discussed the various BIM integration curriculum models including:

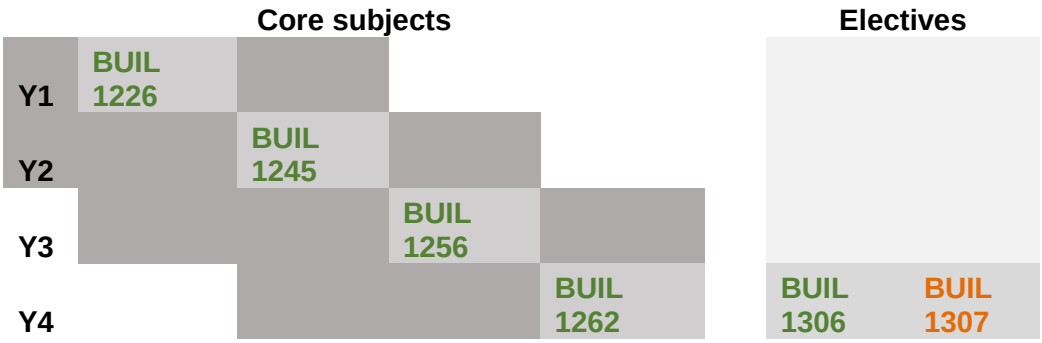
- Detached
- Aware
- Infused
- Combined
- Stream-lined
- Embedded

BIM teaching in BH114: Bachelor of Applied Science (Construction Management) (Honours) closely resembles that of the “infused” approach where there is integration of BIM content in courses across each year level.

Infused/adapted/ intrinsic



BIM teaching starts with BUIL 1226: Introduction to Buildings in year one.



Year two, three and four BIM is taught as part of capstone courses, BUIL 1245: Construction Planning and Design 1, BUIL1256: Construction Planning and Design 2, BUIL1262. In fourth year BIM can also be found being taught in a specialised mode through Research Practice 1 and 1 (BUIL 1306 and 1307) although this would be considered to be an 'elective' mode of teaching. (Refer to Figure 12 for a visual mapping of where these courses are located in relation to each other and the remainder of the program). As earlier explained in section 4.3, infused approach is the most common approach to BIM curriculum integration. The following are the Course Learning Outcomes for these courses:

Course		Learning Outcomes
BUIL 1226: Introduction to Buildings	1	Demonstrate knowledge of the different and significant assets within the construction industry
	2	Identify and describe the diverse features and functions of buildings and structures
	3	Analyse the features of buildings and structures in relation to purpose, function and context
	4	Evaluate the design of buildings and structures
BUIL 1245: Construction Planning and Design 1	1	Estimate and plan the construction of a building
	2	Describe the processes and technologies of construction
	3	Utilise production planning methods using project documentation
	4	Discuss how building systems interface and are constructed
BUIL1256: Construction Planning and Design 2	1	Determine and apply complex construction management theory to your professional practice and/or further study
	2	Professionally communicate to a range of audiences, demonstrating in depth knowledge of the discipline and of the needs of diverse construction management stakeholders
	3	Apply logical critical and creative thinking to analyse, synthesise and apply theoretical knowledge and technical skills to formulate evidenced based solutions to industry problems or issues
	4	Collaborate effectively with others and demonstrate intellectual independence and autonomy to solve problems and/or address industry issues or imperatives
BUIL1262 Construction Planning and Design 3	1	Integrate and apply specialised construction management skills to a current construction project
	2	Develop solutions to identified problems using conflict resolution skills, relevant policy and regulatory frameworks including OH&S;
	3	.Apply theoretical specialised knowledge to address problem based case studies in construction management
	4	Undertake independent research and apply analytical skills to produce tender submissions
	5	Lead and contribute to professional discussions.

The utilisation of threshold concept discussed in section 7 will ensure that 'embedded' approach to BIM teaching is adopted as discussed in section 4.3 This does not necessarily mean that all courses should all teach elements of BIM and this is a misconception. The threshold concept holds that key aptitudes, concepts and skills need to have been reached. The capstone courses offer an important way of assessing threshold concepts and so the framework is well suited. The aspects to achieve *thinking about, thinking and acting like and applying BIM within the context of a construction management professional* that appears

missing at the moment from the areas that industry, past graduates, staff and leading international experts are in two key areas:

- A coordinated and cascaded learning approach to developing fundamental principles and technical skills
- Specific content on strategic organisational behaviours and global market context

There is scope for enrichment in refining BIM in relation to core construction project management skills but the framework of the capstone projects where they are currently taught to some level is a well organised mode to achieve this. With development of the first key area this would then follow. The expertise to provide specific content on the second key area may reside within the staff or it may reside in experts in the industry. The School is well placed to access industry experts and has a long history of managing, coordinating and integrating leading edge content through innovative practitioners so it is not anticipated that this is not unachievable in the short term. This approach already established in many other courses would ensure that we manage the dichotomy of leading and responding to industry needs at the same time. If leading practitioners are not adopting certain behaviours in the industry we should be cautious about focussing efforts on certain areas – this is an important aspect of localising curriculum to the needs of the immediate context. However if staff have experiences and are able to push the boundaries in some aspects this should not be discounted either. This is where the Research Practice 1 and 2 courses are useful mechanisms for exceptional staff expertise and knowledge of international trends can be utilised. There are courses that lend themselves to achieving the other more strategic construction business operational skills envisaged by industry, professional associations, past graduates and staff (namely strategic organisational behaviours and global market context) and this is BUIL 1240 Construction Enterprise which is a fourth year course that has the following course learning outcomes:

1 Identify the financial and business principles and practice required to manage a successful construction business
2 Analyse financial accounts and reports to determine the financial status of an organisation
3 Apply best practice management principles to organisational and project decision making
4 Communicate business solutions for construction industry stakeholders

1.7 Outcome 6 Part D International Institution Case Studies

This section describes our observations of BIM curriculum design and delivery of two international institutions namely; China University of Mining and technology (CUMT) in China and Auburn University in the United States. RMIT signed a CAP agreement with CUMT and therefore this is an ideal case study to explore in detail how BIM curriculum design and delivery is implemented in that program and how changes to our curriculum might affect the student experience. The Auburn University is an exemplar case study as it is arguably the most advanced implementation for an undergraduate program at any institution in the world. We examined curriculum documents as well as conducting interviews with key academics involved in the programs.

1.7.1 CUMT

China University of Mining and Technology (CUMT) is located in Xuzhou, Jiangsu Province and in Beijing. RMIT University signed a CAP program with CUMT in 2012. Under this agreement a set number of students will come to study at RMIT every year starting from 2015. They students will complete 17 courses at RMIT studying in BH114 Bachelor of Applied Science (Construction Management) (Honours) program and will receive exemption of 15 courses as per this agreement. Figure 13 shows the courses that CUMT students will undertake at RMIT.

1.7.2 Curriculum Internationalisation and Industry Globalisation

A representative from the partner institution of the RMIT CM's program was interviewed. He was asked about his view on how BIM can bring internationalisation to the curriculum and the nature of globalisation of the industry brought about by Building Information Modelling.

> *"In Hong Kong, university students are blessed with IT skills. Their universities only introduced BIM related course into their curriculum 2 to 3 years ago. Nevertheless, because graduates have good IT skills, they learned BIM themselves to prepare the site layouts and the construction programs. In India, BIM adoption is taking shape. Most designs of public buildings like hospitals and the airports are involving the use of BIM."*

In the United Kingdom, some developers because the government has mandated the creation of a BIM on their projects. The client and largest procurer of capital works mandating the provision of a BIM at the end of the projects drives the use of Building Information Modelling within the industry. The more frequent use of BIM by the construction industries in some countries has fostered international collaboration. BIM also enables a 24 hour working cycle of a project that involves professionals in different countries. Whereas BIM has the potential to be developed as a common language among professionals, some countries like Australia may lag behind for the fact that BIM is not mandatory for use in the projects.

> *"BIM is not an accepted practice everywhere and the involved techniques changed rapidly…people have to be flexible enough to be responsive to the changes."*

However, the differences may have also triggered more international collaborations.

> *In some areas of the United Kingdom that don't have sufficient staff equipped with BIM related skills, they "employed Indian firms to*

prepared the BIM based construction design and documentation" for their construction projects.

The greater demand of graduates equipped with BIM related skills also motivates the local Indian universities to include BIM in their curriculum. Similarly, universities in many other countries also introduced BIM courses to their students.

"They think that BIM knowledge will add value and enhance employability". "If I was a young graduate, I'd be seriously looking at it (BIM). Because the proficient of BIM will give you a job…" .

Figure 1 Curriculum map of BH114 with courses that will be taken by CUMT students marked by a red frame.

1.7.3 Auburn

Auburn University is located in Auburn, Alabama, United States. It is a public university. McWhorter School of Building Science in Auburn University offers Bachelor of Science in Building Construction (BSCI) Program which is a four-year program focused on construction management. The university implemented BIM curriculum in this program in 2009.

Table 40 maps the BIM related curriculum across various year level in this degree program. The main highlights are that the students are first introduced to BIM in the BSCI 2200: Construction Communications in year 2 semester 2. They use existing BIM models to compare 2D drawings with the 3D models for better understanding. They continue to learn BIM in year 3 semester 1 in BSCI 3500: Construction Info Technology 1 class where they learn how to use BIM software (e.g. Revit, Navisworks). In year 3 semester 2 they take BSCI 3650: Project Controls II in which they learn how to use BIM models for estimating and in BSCI 4601: Project Control III, they learn how to develop 4D schedules. In their final year the students are given the opportunity to do a BIM-based thesis.

Table 42 maps graduate profile and learning outcome of the program as well as the BIM specific course objectives. Based on this it can estimated that BIM related content in the program stands at 9.91% and almost 70% of the BIM content focused on developing technical BIM skills and proficiency in the use of tools such as Revit, Google Sketch Up, NavisWorks, VICO etc. These resources are illustrated in detail in Table 42. Technical heavy aspect of BIM curriculum becomes evident when BIM related content is mapped on our threshold diagram as shown in Figure 14. In the threshold diagram we consider 1st year to be a cognition level, however, for BSCI program year 3 is basically a cognition level and only little BIM content is introduced in year 2. This is for the reason that in US university education system first two years of undergraduate degree programs are generic. Year 4 then teaches BIM content at compatibility level which we have proposed to be at year 2 in our threshold diagram. This presents us with an opportunity to further advanced BIM knowledge at ‘connectivity level’ and ‘integration-self applied level’ in year 3 and year 4 respectively in our construction management undergraduate degree program.

Auburn University: Building Science Curriculum Model

THEMES/ Levels	**Introductory: Cognition Level** Learning to think about BIM environments and develop basic capabilities to operate within a BIM environment as a construction manager.	**Advanced: Compatibility Level** Learning to think, understand and act like a construction manager who integrates people, systems and processes within BIM environments.	**Application: Connectivity Level** Learning to effectively collaborate with others involved in BIM projects and demonstrate intellectual independence and autonomy to solve problems with in BIM environments.	**Integration - Self Applied: Capstones** Learning to lead BIM projects and organisational environments by shaping the world for multiple and diverse connections of people, organisations and systems.
Curriculum model	**Dispensed/ intrinsic - Adv. BIM Elective and BIM capstone course special thesis**			
	Year 1	**Year 2**	**Year 3**	**Year 4**
FUNDAMENTAL PRINCIPLES				
			Cognition Level • Reflect on the differences between project delivery types specifically as they relate to the roles and responsibilities of project team members (BIM application?)	
TECHNICAL SKILLS				
		Cognition Level • demonstrate basic skills of manipulating digital construction drawings and models to retrieve information.	Compatibility Level • Create, modify and use 3D Google Sketchup models for construction • Create basic architectural Building Information Models using Autodesk Revit • Apply features of a simple BIM model on construction management using Autodesk NavisWorks, including interference detection, animated walk-through and 4D construction schedule simulation; • Utilize innovative estimating software including Earthworks, On-Screen Takeoff, and Vico to practice and refine estimating skills	Compatibility Level continued • Create a functional location based schedule using VICO Office • Create a virtual construction model by attaching a schedule to a BIM model using Navisworks • Create a virtual construction model by attaching a schedule to a BIM model using Synchro • Adv. BIM Elective: Create Building Information Modelling (BIM) models, customize and/or use for construction decision making purposes including cost estimation, schedule simulation, collision detection, safety analysis, automated code checking and constructability analysis, able to use advanced animation and simulation methods for virtual construction, familiar with advanced automation technology tool • Voluntary BIM Capstone thesis: BIM Modelling, Clash Detections & Model Revisions, QTO (BIM & by-hand)/Pricing/Recap, Scheduling/ 4-D phasing plan
CONSTRUCTION PROJECT MANAGEMENT SKILLS				
		Cognition Level • demonstrate effective communication by developing questions and answers regarding the drawings and technical specifications. (BIM application?)	Cognition Level • Work in a team to explore new computer applications suitable for construction. Student must communicate with team members, with instructor and with class members, using the computer as a demonstration, teaching and learning tools • Produce standard construction documentation in the context of a simulated project • Generate documentation to support green building certification	
STRATEGIC ORGANISATIONAL BEHAVIOURS				
			Cognition Level • Explain ethical use of ICT • Manage digital files • Define construction ethics during preconstruction and construction phase operations	
GLOBAL MARKET CONTEXT				

Figure13 Mapping of Auburn undergraduate BIM course objectives on threshold framework

Auburn University: Infused/ dispensed/ intrinsic - Adv. BIM Elective and BIM capstone course special thesis

Source: Azhar, S 2014, RE: Your Bachelor Program structure and BIM mapping to T Maqsood, 2 August 2014.

	Yr 1 sem 1 Freshman	Yr 1 sem 2	Yr 2 sem 1 Sophomore	Yr 2 sem 2	Yr 3 sem 1 Junior	Yr 3 sem 2	Yr 4 sem 1 Senior	Yr 4 sem 2
Core subjects	BSCI1100 Intro to Construction	BSCI 2300 Materials & Methods BSCI 2100 Intro to Sust. Constr.	BSCI 2400 Structures for Builders I	**BSCI2200 Construction Communication**	BSCI 3420 Structures for Builders II BSCI 3500/ 3550 Construction Info Technology I BSCI3600 Project Controls II BSCI3700 Construction Safety	ENGL 3040 or 3080 BSCI 3430 Structures for Builders III BSCI4700 Mechanical Systems in Buildings **BSCI3650 Project Controls II** MNGT3810 Management Foundations	**BSCI 4601 Project Control III CIT Lab** BSCI4750 Electrical Systems in Buildings BSCI4600 Project Controls III BSCI4800 Contracting Business	BSCI4990 Thesis - voluntary BIM based BSCI 4850 ConstructionLaw & Risk Mngt.
Electives							BSCI 4860 Advanced Information and Communication Technology for Construction	Business and Construction Management electives

16	16	16	12	15	17	15	13	120	Total credits hours
0	0	0	3	4	4	4	4	19	Credit hours of BIM integrated courses
								16%	Percentage of course credit hours which may contain BIM content
0	0	0	7%	100%	17%	75%	100%		Extent of BIM in course
0.00	0.00	0.00	0.21	4.00	0.68	3.00	4.00	11.89	Extent of BIM expressed as credit hours
0	0	0	2%	27%	4%	20%	31%		Extent of BIM in semester
								9.91%	Extent of BIM in program

Explanation for 75%:

1 credit hour with 60% + 3 credit hours with 80%

0.75

Legend

xxx	**Course contains BIM content**
YYY	BIM dedicated course

Table 42 Estimation of BIM program content in Auburn university's undergraduate program

University	Curriculum model	Syllabus date	Duration of course; Start of BIM	Core-Elective - Program	Course Name	Notes by source	Content	Delivery
Auburn University's Building Science Curriculum Model with BIM capstone special thesis;	**Infused/ dispensed/ intrinsic - Adv. BIM Elective and BIM capstone course special thesis**	2013	4 Year course; BIM starts in Year 2, Sem 2.	Core	BSCI2200 Construction Communication, BSCI 3500/ 3550 Construction Info Technology I, BSCI3650 Project Controls II, BSCI 4601 Project Control III CIT Lab, BSCI4990 Thesis - voluntary BIM based	Salman Azhar 20140802: "The students are first introduced to BIM in the BSCI 2200: Construction Communications (Blueprint reading class). They use existing BIM models to compare 2D drawings with the 3D models for better understanding. After that, they take BSCI 3500: CIT class where they learn how to use BIM software (e.g. Revit, Navisworks). Emphasis in this class is on modeling. In the BSCI 3650: Estimating class, they learn how to use BIM models for estimating. We use Assemble and Vico software for BIM-based estimating. In the BSCI 4601: Scheduling Lab, they learn how to develop 4D schedules. They can do a BIM-based thesis in the final semester.	Introduction to BIM in Year 2 Sem 2 (comparison of 2D to 3D models); Year 3 learning to create models and how to estimate costs. Year 4 scheduling, Advanced BIM elective and voluntary BIM thesis , which includes creation of the model and may include energy modelling.	lectures and lab's

Table 43 Curriculum mapping Auburn University – Part 1/2

Learning objective/ Graduate profile	Learning outcome	BIM specific course objectives	BIM related tools and resources	Extent of BIM integration in program	Specified BIM content in program
1. After review and analysis of construction documentation, the graduating Building Science major will be able to effectively participate in the administration and management of construction project activities from inception through de-construction. 2. After evaluation of the specific circumstances, the graduating Building Science major will be able to identify appropriate methods to operate & communicate effectively in diverse settings. [Only one course referenced the graduate profile and learning outcomes. As the link to the program learning outcomes from program's web page was broken, no additional learning outcomes could be found.]	Upon graduation Graduates of the McWhorter School of Building Science will be able to: 1.20 Estimate the cost of construction work using various methods 1.21 Manage their time effectively. 2.1 Apply written, oral and visual means to communicate effectively in diverse settings 2.2 Employ technology as an effective communication, visualization and management tool 2.3 Operate in teams, including those of diverse composition Upon graduation from Auburn University 2.8 Students will be information literate. 2.9 Students will be able to read analytically and critically 2.12 Students will be able to apply simple mathematical methods to the solution of real-world problems. 2.13 Students will be able to select and use techniques and methods to solve open-ended, ill-defined or multistep problems.	Upon completion of …, students will be able to: • demonstrate basic skills of manipulating digital construction drawings and models to retrieve information. " • Create basic architectural Building Information Models using Autodesk Revit • Apply features of a simple BIM model on construction management using Autodesk NavisWorks, including interference detection, animated walk-through and 4D construction schedule simulation " Utilize innovative estimating software including Earthworks, On-Screen Takeoff, and Vico to practice and refine estimating skills • Create a functional location based schedule using VICO Office • Create a virtual construction model by attaching a schedule to a BIM model using Navisworks • Create a virtual construction model by attaching a schedule to a BIM model using Synchro. • Be able to create Building Information Modeling (BIM) models using currently available software tools in the Market • Be familiar with advanced BIM modeling tools including custom object creation (Revit Families) and BIM + Application Programming Interface (API) integration • Be able to customize and/or use BIM models for construction decision making purposes including cost estimation, schedule simulation, collision detection, safety analysis, automated code checking and constructability analysis • Be able to use advanced animation and simulation methods for virtual construction • Be able to use advanced multimedia applications for project communications • Be familiar with advanced automation technology tools for construction including RFID, Laser Scanning, Photogrammetry, virtual reality (VR) and augmented reality (AR) • Create solutions for complex construction problems by integrating multiple technologies "Thesis activity - Recommended Time BIM Modeling 45% Clash Detections & Model Revisions 10% QTO (BIM & by-hand)/Pricing/Recap 15% Scheduling/4-D phasing plan 10% Miscellaneous Documents/Extras 10% Thesis Package Assembly & Presentation 10%"	Adobe Reader, Revit, (Google Sketch up), Revit 2013, NavisWorks, Vico, Earthworks, Synchro. The School of Building Science holds licenses for Autodesk Revit®, Vico Constructor® and Bentley Architecture®. Other tools recommended for the thesis: Autodesk Ecotect® Analysis, Autodesk Green Building Studio®, IES Virtual Environment · Bentley® and Vico®. Advanced BIM: Autodesk Suite, Vico Office, Navisworks, Tekla, as well as animation and simulation tools Delmia, Flash, Naviworks, Cyclon, advanced multimedia tools, Flash, Camtasia, and automation and robotics tools GPS, RFID, Laser Scanning, Smart Sensors, Photo Modeler.	One BIM inclusive course per semester, starting with Year 2 Sem 2. 16% of credit hours are BIM integrated/dedicated courses incl. the BIM elective options; BIM content per course varies from 7% to 100% (Advanced BIM elective, BIM thesis); Accordong to S Azhar, 70% of the BIM content in the undergraduate course focusses on technical BIM skills.	9.91% of the whole program is spent on learning BIM when all BIM options are chosen

Table 44 Curriculum mapping Auburn University – Part 2/2

1.8 Outcome 7 Threshold Capability Framework for Digital Construction Management Curriculum

We revised the Threshold Capability Framework based upon the feedback and the analysis of the interviews.

Student Threshold Capability Framework for Digital Construction Project Management Curriculum

concepts and capabilities are certain concepts and capabilities within a field that are required to be held to ensure mastery of a particular knowledge domain.
concepts and capabilities are transformative, troublesome, irreversible and integrative.

	Introductory: Cognition Threshold Learning to think about BIM environments and develop basic capabilities to operate within a BIM environment as a construction manager.	**Advanced: Compatability Threshold** Learning to think, understand and act like a construction manager who leads construction projects and integrates people, systems and processes within BIM environments and understands impacts and challenges of compabitibility of people/systems and processes.	**Application: Collaboration Threshold** Learning to understand implications of collaboration and basicskills to effectively collaborate with others involved in BIM projects and demonstrate intellectual independence and autonomy to solve problems within BIM environments.	**Connectivity - Self Applied: Capstones** Learning to lead BIM projects and organ environments by shaping the world for and diverse connections of people, orga and systems; introduction to concept of resilience capability for change. Opport for electives and research projects
	Year 1	Year 2	Year 3	Year 4
NTAL PRINCIPLES	Introduction to the concept of Virtual Construction and BIM. Background information includes Definition, Trends, Stakeholders, Purpose, Implementation, Project Phases, Scope and Interdisciplinary conflicts	Introduction to use of BIM specifically by CM/QS disciplines: safety, quantities, sustainability, project planning, visualisation and communication tool, scheduling, clash detection	Development of Advanced CM /QS Discipline principles application: production planning, lean construction, scheduling, site planning logistics, Project Method Statements, tendering and procurement, constructability	final year capstone experience
.SKILLS	Introduction to data; type, structure and management. Introduction to digital skills for BIM management: Opening, Notations, Sharing, Importing, Exporting, Software: AutoCAD, Sketchup, REVIT, Navisworks	Introduction to skills for BIM production planning ; clash detection, design reviews, model sharing, trade coordination; understanding of data security and access and implications on information flow and workflow; data object libraries. Introduction to CostX, Solibri	Development of advanced Skills: Estimating and BoQ generation, Generation PMS, Introduction to more advanced concepts and skills required: Proof of Concept/Re-engineering/VE, Design>Prefab, Construction sequencing. Consolidation of software use: CostX, Solibri, VICO, Navisworks etc and import/export implications. Data loss and interoperability.	
CTION PROJECT MANAGEMENT SKILLS	Introduction to the idea of use of a Building Information Model as a tool for communication and coordination within simple projects and teams: relating BIM to integrated supply chains, identification of actors in the supply chain and team collaboration, design management, subcontractors and stakeholders	Introduction to idea of using Building Information Modelling as a methodology to enhance project collaboration; impacts of collaboration on Model ownership and legal implications; BIM as part of a contract. Introduction to advanced concepts in using BIM in tendering and procurement; various	Development of advanced concepts in using BIM in strategic procurement; off site manufacturing; client management; complex large scale projects and collaborative environments; opportunities in multi project environments and program management	
: ORGANISATIONAL BEHAVIOURS	Introduction to the Value Proposition for Contractors, subcontractors, Materials Suppliers, Designers, Clients and Regulatory Bodies.	Introduction to implications ofintroducing BIM in organisations; change management, staff training, BIM tools; systems integration, knowledge management; BIM Operational Plans	Introduction and development of advanced concepts of BIM and construction business; exemplars of HR training plans, global systems integration and business models of BIM implementation; BIM and change management	
ARKET CONTEXT	Basic introduction to history of BIM within international context; introduce concept of national standards and protocols, national organisations (BuildSmart), Australian accrediting bodies standards/expectations, BIM in relation to local construction processes; regional norms, values and accepted practices	Introduction to opportunities of using BIM within international construction environments, international accrediting bodies expectations/standards, balancing the tension between local context and universal standards, different ways of doing things in different countries but still operating in a multi country project team environment with various standards;	Development of advanced concepts of managing across different countries on projects; multi disciplinary teams; implications of different cultures on team performance; international sourcing and procurement of materials/building systems/services; outsourcing ; ethical use	

"A threshold concept can be considered as akin to a portal, opening up a new and previously inaccessible way of thinking about something."

H.F. and Land, R. (2003) Threshold concepts and troublesome knowledge: linkages to ways of thinking and practising,In: Rust, C. (ed.), Improving Student Learning - Theory and Practice Ten Years On. Oxford: Oxfor for Staff and Learning Development (OCSLD), pp 412-424.

1.9 Outcome 8 Resources for Digital educational technologies for BIM teaching

Digital Educational Technologies

We have identified five types of digital resources that could support BIM teaching:

1. Building Information Models to introduce and showcase concepts and principles
2. Building Information Models to introduce and develop skills which would require controlled access to the Models by students and and have high levels of interactivity
3. Resource materials to showcase exemplar projects (typically videos)
4. Resources materials to explain and describe particular concepts and show how models can be used and thus enable skill development through self direction (typically videos coupled with other material and testing schemas)
5. Research literature describing concepts and case studies etc.

The resource materials that are suitable for support for BIM curriculum are often readily accessible on the internet and the videos are created and uploaded by various people including:

- the software providers of BIM
- professional bodies as part of Continuing Professional Development
- academics who have helped developed Models
- academics who have been involved in BIM research projects or who teach BIM
- companies and/or project team members of a particular project

Access to Models

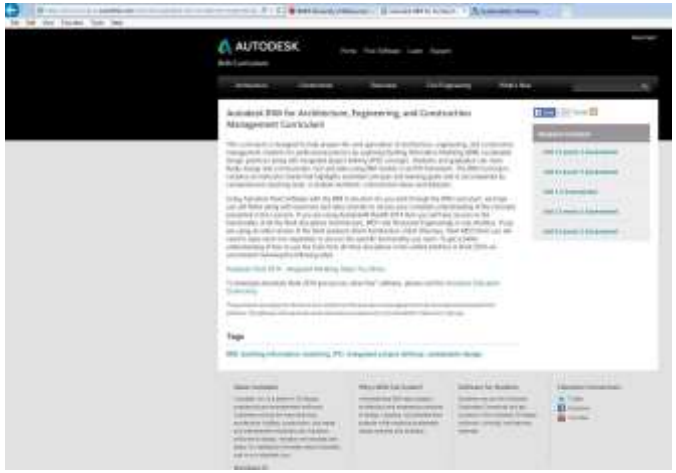
RMIT property services also commissioned a 3D model for its Swanston Academic Building (SAB) building as well as another building in Ho Chi Minh City, Vietnam. Selected members of staff in PCPM have access to this model although it is not a complete Federated Model (that is it doesn't have all the data on all objects in all disciplines and subdisciplines). Academic staff also have access to some industry employers who are willing to provide Models on a limited basis for teaching and/or research. However fundamentally the provision of Models is problematic because of ownership and intellectual property concerns. These matters can be dealt with but it is challenging. The Models often are not comprehensive and detailed enough for teaching purposes. The School would need to address this issue moving forward. (RMIT Navisworks Video.wmv SAB BIM video compiled by Nick Broadbent from BIMEDGE.)

Literature database

We have created a comprehensive database of literature in Endnote which will be made available to the School in our shared drive. The reference list is provided in this report.

Examples of Digital Education Technologies for BIM

The following are some examples of resource material readily available on the internet that staff can draw upon to support curriculum design and delivery. This is not a comprehensive list

Software Supplier Resource Materials (Autodesk): Suite of Materials			
Introduction		Overview with online Units and Assessments	
List of webcasts for construction professionals		BIM Materials for Construction	

BIM Materials for Construction:

Integrated Project Delivery

Fabrication

Planning and logistics

Constructability workflow: videos, podcasts etc.

Individual Videos from Companies and Software Suppliers

Lean and BIM Turner Construction video

BIM Collaboration Video

Revit and Solibri Model Checker Video

importing and exporting and improving interoperability

Implementing BIM in construction

General introduction to using BIM in construction

BIM video The Path to BIM for Small Firms

Autodesk Transforming the BIM Process

Introductory BIM video

The Power of BIM

BIM Value Proposition

1.10 Outcome 9 Videos of staff and employers sharing experiences

The original thinking prior to this project was that we would develop videos as resource materials to support the staff. However it became evident that there are numerous videos and online support materials available. The focus has now shifted to ensuring that the video material represents the local experiences to explain the BIM value proposition and the purpose of why BIM education is important. The videos are in the editing phase. The following are the story boards:

Design and produce exemplar blended materials to support the curriculum design model taken and explain the approach so that existing and future students, staff, industry, professional accrediting bodies and institutional partners will understand our approach

Develop a strategy for the type of blended-learning materials to support the different approaches.

Design and produce 3 online videos (approximately 5-8 minutes in length);

Digital Global Connections and Smart Practices Digital Practices in Global Construction)Video 1)

The Future Digital Construction Professional (Video 2)

Video 1 X 8 minutes

Smart Digital Practices in Global Construction Video 1: captures and explains the changing nature of the international construction industry and the way the programs respond to this; degree is global passport; how BIM is a part of the change; and then industry professional and staff interviews showcasing innovative learning and teaching and projects

Intent	Introduction Kerry	Significance of Vignette from Claudelle	Changes in the industry Vignette from Tayyab	International leader Vignette from	Technology Vignette from Frank
Time	0-20 (20s)	20-50 (30s)	50-90 (40s)	90-130 (40s)	130-170 (40s)
Location	RMIT	RMIT	RMIT	ONLINE/TBC/CHECK	RMIT
Visuals	Portrait Kerry Graphic	Portrait Kerry Portrait Claudelle	Portrait Kerry Portrait Tayyab Graphic – World map Graphic - Curriculum Maps Portrait Tayyab	Alternative- Tayyab might do this as a voiceover reporting style and observations Portrait Kerry Portrait Salman Graphic	Portrait Kerry Portrait Frank Graphic Portrait Frank
Sound	Overview of video Project background Trends in industry Catch 22 Respond or lead Threshold Capability Internationalisation of curriculum	Intro to their company LHG Ownership structure Importance of international culture in companies and thus importance for graduates to be internationally ‘savvy’ Past projects City of Dreams International community is the way of the future	Pathways CUMT and others? Global learning by design Curriculum mapping	Question: Experiences over the last 5 years in developing their curriculum Challenges Philosophy Changes Future directions Collaboration with RMIT	Question: Software Technology Principles Information management Importance of data in construction Importance of data management skills Teach principles rather than software

Intent	Sustainability Vignette from Sarah	Management Vignette from Peter	Internationalisation Vignette from Tayyab	Wrap up Kerry
Time	170-200 (30s)	200-240 (40s)	240-280 (40s)	280-300 (20s)
Location	RMIT	RMIT	RMIT	RMIT
Visuals	Portrait Kerry (or voice) Portrait Sarah Graphic Portrait Sarah	Portrait Kerry (or voice) Portrait Peter	Portrait Tayyab	Graphic of Principles
Sound	Question: Non technical construction professional – what she teaches How this course would connect	Question: What does Peter teach and how can see changing his course in the future Refer to Threshold diagram	Question: Last threshold theme Pick up on how we envision responding to Claudelles points Graduates – is this too much for them? Too advanced? Is this masters level? Refer to AQF levels? Introduction – identify the course that this would sit within	

Intent	Introduction	Innovation Vignette from Claudelle	Innovation Vignette from Medy's org	Innovation Training Vignette from Radley Vignette from Bob Baird Defense	Innovation Hansen and Yunken (talk to Louise)	Wrap up
Time	0-20 (20s)	20-110 (90s)	110-200 (90s)	200-290 (90s) 290-380 (90s)	380-460 (80s)	460-480 (20s)
Location	RMIT	RMIT	RMIT	MBA V /TBC	CHECK	RMIT
Visuals						
Sound	Innovation What we think is innovative now – changes But then we need to catch up in Australia Inconsisent adoption patterns EBusiness study Collaborative Platforms study Lead the world in D&C (D&B) PPPs and alliancing – which are procurement strategies that underpin digital collaboration and yet we have been tardy in adopting BIM and other advanced IM tactics Research is keeping in pace – just – but practice isn't on an industry McGraw Hill survey But we have some exemplars	Introduce LHG Explain innovative practice Perhaps the journey ? Innovation at Sydney Opera House- City of Dreams-Collins St	Introduce Hindmarsh Explain innovative practice – SA project	Introduce MBA V Explain Lab Largest capital works procurement agency Biggest spend What do they see now? What innovations are they putting place as a client to catalyse change?	Introduce Hansen and Yunken Explain Hospital project	Industry, research, education and policy making

Video 3 - 5 minutes

Future Digital Construction Professional Video 2: outlined some fundamental theoretical principles that all the stakeholders agree to in relation to graduate profiles.

Intent	Introduction Kerry	Changes in the industry Vignette from Medy's org	Changes in the industry 2 Vignette from Claudelle	International trends Vignette from Kerry	Recent Graduate experiences and observations Vignette from Dan	Wrap up Kerry
Time	0-20 (20s)	20-120 (100s)	120-220 (100s)	220-320 (100s)	320-380 (60s)	380-420 (20s)
	RMIT	RMIT	RMIT	ONLINE/TBC/CHECK	RMIT	RMIT
Visuals				David UK Map Cover of report		
Sound	Introduce BIM Introduce Threshold Capability	What sort of industry do I see in the future? What sort of graduate do we want to see?	I am IT support…the beginning NexusPoint Solutions What sort of industry have I seen? My experiences in this space… How I see the future? What I would like to see in a graduate…	Involvement in UK Taskforce Recent young professional report etc Some future thoughts	My experiences at RMIT – when My experiences in Sweden/Skanska My final year project – desal plant/research project My experiences in industry –	Technical and non technical skills National and international accrediting bodies Resilience Time of transformation

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1.12 Appendices

1.1.1 Interview guides: Employers

Consent forms of interview participant have been signed in advance by the participant.

Thank you for agreeing to participate in RMIT's research "Global Passport through Co-integration of Construction Immersive Environments". We are very interested to hear about your experiences with BIM teaching and your opinion on how RMIT could improve its curriculum to equip graduates to study and work anywhere in the world.

• The purpose of this study is to investigate the best and most appropriate way of integrating Building Information Modelling (BIM) into the curriculum of RMIT's construction and project management programs in Australia, on overseas campuses and at our partner universities in Asia.

• We are audio-recording this interview so that we can make sure to capture your thoughts, opinions and ideas. Could you, please, confirm that you agree to the audio-recording and to its subsequent transcription?

• Please be assured that all the information you provide is kept private and confidential. Your name will not be attached to the interview. Would you like to pick your own pseudonym?

• Please remember, that you may refuse to answer any question or withdraw from the study at any time.

• If you have any questions now or after you have completed the interview, you can always contact the Chief Investigator or a research team member whose names and phone numbers are on the top page of your copy of the Participation, Information and Consent Form. Are you ready to begin the interview?

7. Could you, please, start by introducing yourself?
   - Current job, for how long
   - What kind of a company construction company/ project management company/ architectural/ engineering/ business
   - Size of company (number of employees, project values, national/international company)
   - What kind of construction field – buildings – commercial, residential, volume builder; infrastructure – what kind of projects; unique selling point

8. Can you tell us about your current experiences with BIM?
   - For how long has BIM been used in your organisation? Why is BIM integrated in your organisation?
   - How and to what extent BIM is used in your company
   - Is it restricted to a certain type of project, stage of design and/or documentation? Why?
   - Are you using BIM in international projects? If yes, how? If no, why not
   - Can you describe how BIM has provided any transformation in thinking? How did you think/ act/ perform business before/ after?
   - Can you, please, describe anything about using BIM in your company that you have found challenging? Can you describe your experience in overcoming this problem, please?

Moving on to the focus of our research, namely BIM in higher education:

9. Can you describe your experiences with the current level of preparation of graduates with regards to BIM?
   - What are the BIM skills and knowledge you currently expect a from a university graduate?
   - How have recently employed graduates stood up to your expectations?
   - Do you offer BIM training for your current employees? If so why, how and what is being taught?
   - From your experience, which BIM skills and knowledge do your think would be particularly important for graduates to be work ready as the construction industry becomes increasingly globalised?

RMIT is a 'global university' with many international students and partner universities in China, Singapore, Hong Kong, Sri Lanka and Indonesia as well as campuses in Vietnam and Spain. RMIT is in the process of internationalising its curriculum. "Internationalisation of the curriculum" has been defined as

> "the incorporation of an international and intercultural dimension into the content of the curriculum as well as the teaching and learning arrangements and support services of a program of study." (Leask 2009, p. 209).

The key terms here are "international" and, "intercultural" which include social and environmental awareness.

10. Can you tell us how you see the development of BIM in an increasingly globalised construction industry?

- Where do you see challenges for BIM and how do you think they will be overcome?
- How could BIM add value to the internationalisation of the curriculum of construction and project managers?

11. We have developed a draft thresholds diagram for an undergraduate BIM curriculum, which we have sent to you. The objective was to create a holistic and BIM embedded approach.
    We would like to take this opportunity to discuss and reflect on this diagram.
    - Could you tell us your initial thoughts, please?
    - How do you think, BIM skills and knowledge should best be integrated into the program?
    - At what point in the course and to what level of achievement, do you think, should the topics be taught in a construction or project management program? Why?
    - Do you have any suggestions for teaching BIM that may help students transform their thinking or help them understand a difficult BIM related concept?

12. Before we finish, is there anything that you would like to share with us on the topics of BIM or the internationalisation of university education?

This concludes our interview. Thank you so much for (coming and) sharing your thoughts, experiences and opinions with us. If you have any additional information that you did not get to say in the interview, please feel free to write to us. Once we have collected all the interview data from the various participants, we will analyse it and use the findings to develop the framework for integrating BIM into the curriculum. We will disseminate our approach through reports and journal papers and perhaps a public forum, to which you will be invited.

Finally, we would like to know if you would be interested in appearing in a video on this research. We will produce three videos which will showcase our approach. Your participation in any video is entirely voluntary. The exact topics and scripts will be decided at a later stage, once we have established the first outcomes of this study. At this point in time, we are only collecting expressions of interest. Would you be willing to, perhaps, participate in a video in which you could present your thoughts, experiences or opinions?

Thank you for your time and openness. I will now stop the recording.

References:

Leask, B 2009, 'Using Formal and Informal Curricula to Improve Interactions Between Home and International Students', *Journal of Studies in International Education*, vol. 13, no. 2, pp. 205-21.

1.1.2 Interview guide: Accreditation bodies

Consent forms of interview participant have been signed in advance by the participant.

Thank you for agreeing to participate in RMIT's research "Global Passport through Co-integration of Construction Immersive Environments". We are very interested to hear about your experiences with BIM teaching and your opinion on how RMIT could improve its curriculum to equip graduates to study and work anywhere in the world.

• The purpose of this study is to investigate the best and most appropriate way of integrating Building Information Modelling (BIM) into the curriculum of RMIT's construction and project management programs in Australia, on overseas campuses and at our partner universities in Asia.

• We are audio-recording this interview so that we can make sure to capture your thoughts, opinions and ideas. Could you, please, confirm that you agree to the audio-recording and to its subsequent transcription?

• Please be assured that all the information you provide is kept private and confidential. Your name will not be attached to the interview. Would you like to pick your own pseudonym?

• Please remember, that you may refuse to answer any question or withdraw from the study at any time.

• If you have any questions now or after you have completed the interview, you can always contact the Chief Investigator or a research team member whose names and phone numbers are on the top page of your copy of the Participation, Information and Consent Form. Are you ready to begin the interview?

13. Could you, please, start by introducing yourself?
    - Current job, for how long
    - What kind of accreditation body, national/ international accreditations
    - How may certified programs, how many graduates per year
    - Last time accreditation criteria were revised, frequency of revisions

14. Can you tell us about your current experiences with BIM?
    - For how long has your body been aware of BIM? Why?
    - How and to what extent BIM is part of your accreditation criteria? If not yet, when and how are you thinking to incorporate BIM?
    - Is it restricted to a country? Why?
    - Can you describe how your accreditation organisation is viewing the adoption of BIM. Do you believe it is providing a transformation in thinking? How did your members think/ act/ perform business before/ after?
    - Can you, please, describe anything about introducing BIM in your criteria that you have found challenging? Can you describe your experience in overcoming this problem, please?

Moving on to the focus of our research, namely BIM in higher education:

15. Can you describe your experiences with the current level of preparation of graduates with regards to BIM?
    - What are the BIM skills and knowledge you currently expect a from a university graduate?
    - How have recently employed graduates stood up to your expectations?
    - Do you offer BIM training for your current members? If so why, how and what is being taught?
    - From your experience, which BIM skills and knowledge do your think would be particularly important for graduates to be work ready as the construction industry becomes increasingly globalised?

RMIT is a 'global university' with many international students and partner universities in China, Singapore, Hong Kong, Sri Lanka and Indonesia as well as campuses in Vietnam and Spain. RMIT is in the process of internationalising its curriculum. "Internationalisation of the curriculum" has been defined as

> "the incorporation of an international and intercultural dimension into the content of the curriculum as well as the teaching and learning arrangements and support services of a program of study." (Leask 2009, p. 209).

The key terms here are "international" and, "intercultural" which include social and environmental awareness.

16. Can you tell us how you see the development of BIM in an increasingly globalised construction industry?
    - Where do you see challenges for BIM and how do you think they will be overcome?
    - How could BIM add value to the internationalisation of the curriculum of construction and project managers?

17. We have developed a draft thresholds diagram for an undergraduate BIM curriculum, which we have sent to you. The objective was to create a holistic and BIM embedded approach.
    We would like to take this opportunity to discuss and reflect on this diagram.
    - Could you tell us your initial thoughts, please?
    - How do you think, BIM skills and knowledge should best be integrated into the program?
    - At what point in the course and to what level of achievement, do you think, should the topics be taught in a construction or project management program? Why?
    - Do you have any suggestions for teaching BIM that may help students transform their thinking or help them understand a difficult BIM related concept?

18. Before we finish, is there anything that you would like to share with us on the topics of BIM or the internationalisation of university education?

This concludes our interview. Thank you so much for (coming and) sharing your thoughts, experiences and opinions with us. If you have any additional information that you did not get to say in the interview, please feel free to write to us. Once we have collected all the interview data from the various participants, we will analyse it and use the findings to develop the framework for integrating BIM into the curriculum. We will disseminate our approach through reports and journal papers and perhaps a public forum, to which you will be invited.

Finally, we would like to know if you would be interested in appearing in a video on this research. We will produce three videos which will showcase our approach. Your participation in any video is entirely voluntary. The exact topics and scripts will be decided at a later stage, once we have established the first outcomes of this study. At this point in time, we are only collecting expressions of interest. Would you be willing to, perhaps, participate in a video in which you could present your thoughts, experiences or opinions?

Thank you for your time and openness. I will now stop the recording.

References:

Leask, B 2009, 'Using Formal and Informal Curricula to Improve Interactions Between Home and International Students', *Journal of Studies in International Education*, vol. 13, no. 2, pp. 205-21.

1.1.3 Interview guide: Recent Graduates

Consent forms of interview participant have been signed in advance by the participant.

Thank you for agreeing to participate in RMIT's research "Global Passport through Co-integration of Construction Immersive Environments". We are very interested to hear about your experiences with BIM teaching and your opinion on how RMIT could improve its curriculum to equip graduates to study and work anywhere in the world.

• The purpose of this study is to investigate the best and most appropriate way of integrating Building Information Modelling (BIM) into the curriculum of RMIT's construction and project management programs in Australia, on overseas campuses and at our partner universities in Asia.

• Please be assured that all the information you provide is kept private and confidential. Unless you wish otherwise, you will be de-identified. We will share the data with management and other bodies in aggregate form, except for individual comments which may be transcribed verbatim. Identifying references of shared individual comments which are not crucial for the analysis will be removed or obscured.

• If you request to be identified in the research outputs, then we will comply with this request provided this does not compromise the privacy of others.

• We are audio-recording this interview so that we can make sure to capture your thoughts, opinions and ideas. You may reserve any information and offer it as an 'off the record' statement after the interview. 'Off the record' statements is information which you believe to be important for the research but which you do not want to be ascribed to yourself personally. You may provide such 'off the record' information after the audio-recording of the interview has ceased.

I shall now start the audio-recording. Could you, please, confirm that you agree to the audio-recording and to its subsequent transcription?

• If you wish to be identified in the research outputs, could you please state your name?

• Please remember that you may refuse to answer any question or withdraw from the study at any time without giving reasons. You may also withdraw any statement or part thereof provided the data has not yet been processed.

• If you have any questions now or after you have completed the interview, you can always contact the Chief Investigator or a research team member whose names and phone numbers are on the top page of your copy of the Participation, Information and Consent Form. Are you ready to begin the interview?

1. Could you, please, start by introducing yourself?
    - Current job, for how long, time since graduation, university
    - What kind of a company construction company/ project management company/ architectural/ engineering/ business
    - Size of company (number of employees, project values, national/international company)
    - What kind of construction field – buildings – commercial, residential, volume builder; infrastructure – what kind of projects

We would like to learn more about how you have learnt BIM

2. Can you tell us about your learning experiences with BIM?
    - How did you learn BIM? (self-taught, company training course, university?
    - Do you think that this was the optimum way of learning BIM? Please explain what was good/ not so good; advantages/ disadvantage
    - What are the BIM skills and knowledge that you have learnt in your training/ university/ self-taught course?
    - Are you applying these now in your workplace? How?
    - Which of the learnt BIM skills and knowledge are you <u>not</u> using? Why?
    - What are the BIM skills and knowledge that you feel you are still lacking? Why are these important to you?
    - Thinking back to your BIM learning, can you tell us about which teaching techniques were used and what did you think about them - approaches to teaching and learning
    - Which modes of delivery were used?
    - Which resources were available to you?
    - Assessments.

3. Can you tell us about your current experiences with BIM?
    - For how long have you been using BIM?
    - How and to what extent are you using BIM?
    - Is it restricted to a certain type of project, stage of design and/or documentation? Why?
    - Are you using BIM in international projects? If yes, how? If no, why not
    - Can you describe how BIM has transformed your thinking? How did you think/ act/ perform business/ tasks before/ after?
    - Can you, please, describe anything about using BIM that you have found troublesome or challenging? Can you describe your experience in overcoming this problem, please?

Moving on to the focus of our research, namely BIM in higher education: RMIT is a 'global university' with many international students and partner universities in China, Singapore, Hong Kong, Sri Lanka and Indonesia as well as campuses in Vietnam and Spain. RMIT is in the process of internationalising its curriculum. "Internationalisation of the curriculum" has been defined as

> "the incorporation of an international and intercultural dimension into the content of the curriculum as well as the teaching and learning arrangements and support services of a program of study." (Leask 2009, p. 209).

The key terms here are "international" and, "intercultural" which include social and environmental awareness.

4. Can you tell us how you see the development of BIM in an increasingly globalised construction industry?
   - Where do you see challenges for BIM and how do you think they will be overcome?
   - How could BIM add value to the internationalisation of the curriculum of construction and project managers?

5. We have developed a draft thresholds diagram for an undergraduate BIM curriculum, which we have sent to you. The objective was to create a holistic and BIM embedded approach.
   We would like to take this opportunity to discuss and reflect on this diagram.
   - Could you tell us your initial thoughts, please?
   - How do you think, BIM skills and knowledge should best be integrated into the program?
   - At what point in the course and to what level of achievement, do you think, should the topics be taught in a construction or project management program? Why?
   - Do you have any suggestions for teaching BIM that may help students transform their thinking or help them understand a difficult BIM related concept?

6. Before we finish, is there anything that you would like to share with us on the topics of BIM or the internationalisation of university education?

This concludes our interview. Thank you so much for (coming and) sharing your thoughts, experiences and opinions with us. If you have any additional information that you did not get to say in the interview, please feel free to write to us. Once we have collected all the interview data from the various participants, we will analyse it and use the findings to develop the framework for integrating BIM into the curriculum. We will disseminate our approach through reports and journal papers and perhaps a public forum, to which you will be invited.

Finally, we would like to know if you would be interested in appearing in a video on this research. We will produce three videos which will showcase our approach. Your participation in any video is entirely voluntary. The exact topics and scripts will be decided at a later stage, once we have established the first outcomes of this study. At this point in time, we are only collecting expressions of interest. Would you be willing to, perhaps, participate in a video in which you could present your thoughts, experiences or opinions?

Thank you for your time and openness. I will now stop the recording. Is there anything that you would like to add 'off the record'?

References:

Leask, B 2009, 'Using Formal and Informal Curricula to Improve Interactions Between Home and International Students', *Journal of Studies in International Education*, vol. 13, no. 2, pp. 205-21.

1.12.1 Interview guide: International educators (program managers)

Consent forms of interview participant have been signed in advance by the participant.

Thank you for agreeing to participate in RMIT's research "Global Passport through Co-integration of Construction Immersive Environments". We are very interested to hear about your experiences with BIM teaching and your opinion on how RMIT could improve its curriculum to equip graduates to study and work anywhere in the world.

• The purpose of this study is to investigate the best and most appropriate way of integrating Building Information Modelling (BIM) into the curriculum of RMIT's construction and project management programs in Australia, on overseas campuses and at our partner universities in Asia.

• Please be assured that all the information you provide is kept private and confidential. Unless you wish otherwise, you will be de-identified. We will share the data with management and other bodies in aggregate form, except for individual comments which may be transcribed verbatim. Identifying references of shared individual comments which are not crucial for the analysis will be removed or obscured.

• If you request to be identified in the research outputs, then we will comply with this request provided this does not compromise the privacy of others.

• We are audio-recording this interview so that we can make sure to capture your thoughts, opinions and ideas. You may reserve any information and offer it as an 'off the record' statement after the interview. 'Off the record' statements is information which you believe to be important for the research but which you do not want to be ascribed to yourself personally. You may provide such 'off the record' information after the audio-recording of the interview has ceased.

I shall now start the audio-recording. Could you, please, confirm that you agree to the audio-recording and to its subsequent transcription?

• If you wish to be identified in the research outputs, could you please state your name?

• Please remember that you may refuse to answer any question or withdraw from the study at any time without giving reasons. You may also withdraw any statement or part thereof provided the data has not yet been processed.

• If you have any questions now or after you have completed the interview, you can always contact the Chief Investigator or a research team member whose names and phone numbers are on the top page of your copy of the Participation, Information and Consent Form. Are you ready to begin the interview?

1. Could you, please, start by introducing yourself and your school?
    - Current position, for how long
    - What kind of a university/ school - construction management/ project management/ architectural/ engineering
    - Size of school (number of students in school/program, growth, national/ international curriculum)
    - Growth/ direction of construction management program
    - Specialty of school/ unique selling point?

We would like to learn more about how you are using BIM in your school to educate students.

2. Can you tell us about your current teaching experiences with BIM?
    - What are the BIM skills and knowledge that you are teaching in your course? - Content
    - Is there research on BIM within the school?
    - Which teaching techniques are you using? How is it taught - approaches to teaching and learning
    - Which modes of delivery are you using?
    - Which resources are available to you?
    - Assessments

3. Could you please reflect on the development of teaching of BIM in your school and describe your experiences?
    - Can you, please, describe how BIM has impacted to your teaching in the past and now?
    - Can you describe the difficulties that students had in learning BIM and how you have helped students to overcome these?
    - Can you, please, describe the challenges or opportunities in teaching BIM at your school?
    - What future directions in general do you see for the BIM education in your school?

RMIT is a 'global university' with many international students and partner universities in China, Singapore, Hong Kong, Sri Lanka and Indonesia as well as campuses in Vietnam and Spain. RMIT is in the process of internationalising its curriculum. "Internationalisation of the curriculum" has been defined as

> "the incorporation of an international and intercultural dimension into the content of the curriculum as well as the teaching and learning arrangements and support services of a program of study." (Leask 2009, p. 209).

The key terms here are “international” and, “intercultural” which include social and environmental awareness.

4. Can you tell us how you see the development of BIM in an increasingly globalised construction industry? How could BIM add value to the internationalisation of the curriculum of construction and project managers?

Moving on to the focus of our research, namely BIM in higher education:

5. We have developed a draft thresholds diagram for an undergraduate BIM curriculum, which we have sent to you. The objective was to create a holistic and BIM embedded approach.
   We would like to take this opportunity to discuss and reflect on this diagram.
   - Could you tell us your initial thoughts, please?
   - How do you think, BIM skills and knowledge should best be integrated into the program?
   - At what point in the course and to what level of achievement, do you think, should the topics be taught in a construction or project management program? Why?
   - Do you have any suggestions for teaching BIM that may help students transform their thinking or help them understand a difficult BIM related concept?

6. Before we finish, is there anything that you would like to share with us on the topics of BIM or the internationalisation of university education?

This concludes our interview. Thank you so much for (coming and) sharing your thoughts, experiences and opinions with us. If you have any additional information that you did not get to say in the interview, please feel free to write to us. Once we have collected all the interview data from the various participants, we will analyse it and use the findings to develop the framework for integrating BIM into the curriculum. We will disseminate our approach through reports and journal papers and perhaps a public forum, to which you will be invited.

Finally, we would like to know if you would be interested in appearing in a video on this research. We will produce three videos which will showcase our approach. Your participation in any video is entirely voluntary. The exact topics and scripts will be decided at a later stage, once we have established the first outcomes of this study. At this point in time, we are only collecting expressions of interest. Would you be willing to, perhaps, participate in a video in which you could present your thoughts, experiences or opinions?

Thank you for your time and openness. I will now stop the recording.

Is there anything that you would like to add ‘off the record’?

References:

Leask, B 2009, 'Using Formal and Informal Curricula to Improve Interactions Between Home and International Students', *Journal of Studies in International Education*, vol. 13, no. 2, pp. 205-21.

1.1.4 Focus group guide: RMIT Staff Focus Group

Consent forms of interview participant have been signed in advance by the participants.

Thank you for agreeing to participate in RMIT's research "Global Passport through Co-integration of Construction Immersive Environments". We are very interested to hear about your experiences with BIM teaching and your opinion on how RMIT could improve its curriculum to equip graduates to study and work anywhere in the world.

• The purpose of this study is to investigate the best and most appropriate way of integrating Building Information Modelling (BIM) into the curriculum of RMIT's construction and project management programs in Australia, on overseas campuses and at our partner universities in Asia.

• The purpose of this focus group is to develop models for a holistic curriculum design and delivery approach that moves us towards the identified potential goal of a fully integrated virtual construction immersive environment student experience.

• The success of the focus group depends on the participation of everyone. Please keep your communications within the group and do not have side conversation.

• Please note that we are trying to keep all the information you provide private and confidential, but that due to the small number of staff at PCPM and in this meeting complete anonymity and confidentiality cannot be guaranteed. Unless you wish otherwise, you will be de-identified. We will share the data with management and other bodies in aggregate form, except for individual comments which may be transcribed verbatim. Identifying references of shared individual comments which are not crucial for the analysis will be removed or obscured.

• If you request to be identified in the research outputs, then we will comply with this request provided this does not compromise the privacy of other participants.

• We also ask all of you to keep confidential any information provided in this focus group discussion.

• We are audio-recording this interview so that we can make sure to capture your thoughts, opinions and ideas. If you wish, you may remain silent during the duration of the recording and merely observe the discussion. You may also reserve any information and offer it as an 'off the record' statement after the meeting. 'Off the record' statements is information which you believe to be important for the research but which you do not want to be ascribed to yourself personally. You may provide such 'off the record' information after the audio-recording of the interview has ceased. You may provide this information verbally and in privacy to the Research Project Officer after this meeting.

I shall now start the audio-recording. Could you, please, confirm that you agree to the audio-recording and to its subsequent transcription?

• If there is anyone who wishes to be identified in the research outputs, could you please state your name?

• Please remember that you may refuse to answer any question or withdraw from the study at any time without giving reasons. You may also withdraw any statement or part thereof provided the data has not yet been processed.

• If you have any questions now or after you have completed the interview, you can always contact the Chief Investigator or a research team member whose names and phone numbers are on the top page of your copy of the Participation, Information and Consent Form. Are you ready to begin the interview?

1. Could you, please, start by introducing yourself?
   - Current position, teaching which courses, for how long
   - Size of course/-s, taught nationally/ internationally?
   - Significance of course/ -s within the program?

We would like to learn more about how you are using BIM in your course/ -s to educate students.

2. Can you tell us about your past & current teaching experiences with BIM?
   - Are you teaching BIM in your course?
   - What are the BIM skills and knowledge that you are teaching in your course? - Content
   - Which teaching techniques are you using? How is it taught - approaches to teaching and learning
   - Which modes of delivery are you using?
   - Which resources are available to you?
   - Assessments

3. Could you please reflect on your current teaching of BIM and describe your experiences?
   - Can you, please, describe how BIM has impacted to your teaching in the past and now?
   - Can you, please, describe the difficulties that students had in learning BIM and how you have helped students to overcome these?
   - What do you think are the strengths of your own BIM teaching? Why?

- What do you find challenging in teaching BIM?
- Where do you see opportunities for your own BIM teaching?

RMIT is a 'global university' with many international students and partner universities in China, Singapore, Hong Kong, Sri Lanka and Indonesia as well as campuses in Vietnam and Spain. RMIT is in the process of internationalising its curriculum. "Internationalisation of the curriculum" has been defined as

> "the incorporation of an international and intercultural dimension into the content of the curriculum as well as the teaching and learning arrangements and support services of a program of study." (Leask 2009, p. 209).

The key terms here are "international" and, "intercultural" which include social and environmental awareness.

4. Can you tell us how you see the development of BIM in an increasingly globalised construction industry? How could BIM add value to the internationalisation of the curriculum of construction and project managers?
   - Please describe how BIM in a global context may prove challenging. How do you suggest this problem may be overcome?
     - Which role do you think BIM could play in preparing graduates to be work ready, global in outlook and competence, environmentally aware and responsible, culturally and socially aware, active and lifelong learners, innovative.

Moving on to the focus of our research, namely BIM in higher education:

5. We have developed a draft thresholds diagram for an undergraduate BIM curriculum, which we have sent to you. The objective was to create a holistic and BIM embedded approach.
   We would like to take this opportunity to discuss and reflect on this diagram.
   - Could you tell us your initial thoughts, please?
   - If you were the key decision maker, how would you integrate BIM skills and knowledge into the courses in your own university/ school?
   - At what point in the course and to what level of achievement, do you think, should the topics be taught in a construction or project management course? Why?
   - Do you have any suggestions for teaching BIM that may help students transform their thinking or help them understand a difficult BIM related concept

6. Before we finish, is there anything that you would like to share with us on the topics of BIM or the internationalisation of university education?

This concludes our interview. Thank you so much for coming and sharing your thoughts, experiences and opinions with us. If you have any additional information that you did not get to say in the focus group, please feel free to write to us. Once we have collected all the interview data from the various participants, we will analyse it and use the findings to develop the framework for integrating BIM into the curriculum. We will disseminate our approach through reports and journal papers and perhaps a public forum, to which you will be invited.

Finally, we would like to know if you would be interested in appearing in a video on this research. We will produce three videos which will showcase our approach. Your participation in any video is entirely voluntary. The exact topics and scripts will be decided at a later stage, once we have established the first outcomes of this study. At this point in time, we are only collecting expressions of interest. Would you be willing to, perhaps, participate in a video in which you could present your thoughts, experiences or opinions?

Thank you for your time and openness. I will now stop the recording.

References:

Leask, B 2009, 'Using Formal and Informal Curricula to Improve Interactions Between Home and International Students', *Journal of Studies in International Education*, vol. 13, no. 2, pp. 205-21.

1.1.5 Interview guide: Head of School of PCPM

Consent forms of interview participant has been signed in advance by the participant.

Thank you for agreeing to participate in RMIT's research "Global Passport through Co-integration of Construction Immersive Environments". We are very interested to hear about your experiences with BIM teaching and your opinion on how RMIT could improve its curriculum to equip graduates to study and work anywhere in the world.

• The purpose of this study is to investigate the best and most appropriate way of integrating Building Information Modelling (BIM) into the curriculum of RMIT's construction and project management programs in Australia, on overseas campuses and at our partner universities in Asia.

• Please be assured that all the information you provide is kept private and confidential. Unless you wish otherwise, you will be de-identified. We will share the data with management and other bodies in aggregate form, except for individual comments which may be transcribed verbatim. Identifying references of shared individual comments which are not crucial for the analysis will be removed or obscured.

• If you request to be identified in the research outputs, then we will comply with this request provided this does not compromise the privacy of others.

• We are audio-recording this interview so that we can make sure to capture your thoughts, opinions and ideas. You may reserve any information and offer it as an 'off the record' statement after the interview. 'Off the record' statements is information which you believe to be important for the research but which you do not want to be ascribed to yourself personally. You may provide such 'off the record' information after the audio-recording of the interview has ceased.

I shall now start the audio-recording. Could you, please, confirm that you agree to the audio-recording and to its subsequent transcription?

• If you wish to be identified in the research outputs, could you please state your name?

• Please remember that you may refuse to answer any question or withdraw from the study at any time without giving reasons. You may also withdraw any statement or part thereof provided the data has not yet been processed.

• If you have any questions now or after you have completed the interview, you can always contact the Chief Investigator or a research team member whose names and phone numbers are on the top page of your copy of the Participation, Information and Consent Form. Are you ready to begin the interview?

1. Could you, please, start by introducing yourself and your school?
    - Current position, for how long
    - What kind of a university/ school - construction management/ project management/ architectural/ engineering
    - Size of school (number of students in school/program, growth, national/ international curriculum)
    - Growth/ direction of construction management program
    - Specialty of school/ unique selling point?

We would like to learn more about how you are using BIM in your course/ -s and school or university to educate students.

2. Can you tell us about your past & current experiences with BIM?
    - In which courses was/is BIM taught?
    - Was/ is there research on BIM within the school?
    - Which teaching approaches were/ you using? How was/is it taught - approaches to teaching and learning
    - Which modes of delivery?

3. Could you please reflect on the development of teaching of BIM in your school and describe your experiences?
    - What factors have shaped the approach of teaching BIM at you school? (accreditation bodies, industry demands, staff champions)
    - What do you find challenging in teaching BIM at your school?
    - Where do you see opportunities for your teaching BIM at your school?
    - What future directions in general do you see for the BIM education in your school?

RMIT is a 'global university' with many international students and partner universities in China, Singapore, Hong Kong, Sri Lanka and Indonesia as well as campuses in Vietnam and Spain. RMIT is in the process of internationalising its curriculum. "Internationalisation of the curriculum" has been defined as

> "the incorporation of an international and intercultural dimension into the content of the curriculum as well as the teaching and learning arrangements and support services of a program of study." (Leask 2009, p. 209).

The key terms here are "international" and, "intercultural" which include social and environmental awareness.

4. Can you tell us how you see the development of BIM in an increasingly globalised construction industry? How could BIM add value to the internationalisation of the curriculum of construction and project managers?
    - Given your responsibility within the university in the development and oversight of the international affairs, including policies related to international student enrolments, overseas exchanges and research collaboration, could you give us any insights into how our construction management course might be shaped for the future?
    - How do you think BIM could confirm our position as leaders in higher education construction programs?
    - What are your thoughts on student mobility? Will it contribute to our international profile? Does BIM have a place in the undergraduate programs? How do you think BIM could improve our graduate profiles?

Moving on to the focus of our research, namely BIM in higher education:

5. We have developed a draft thresholds diagram for an undergraduate BIM curriculum, which we have sent to you. The objective was to create a holistic and BIM embedded approach. We would like to take this opportunity to discuss and reflect on this diagram.
    - Could you tell us your initial thoughts, please?
    - Ideally, how would you integrate BIM skills and knowledge into the courses in your school?
    - At what point in the course and to what level of achievement, do you think, should BIM be taught in a construction or project management course? Why?
    - Do you have any suggestions for teaching BIM that may help students transform their thinking or help them understand a difficult BIM related concept

6. Before we finish, is there anything that you would like to share with us on the topics of BIM or the internationalisation of university education?

This concludes our interview. Thank you so much for (coming and) sharing your thoughts, experiences and opinions with us. If you have any additional information that you did not get to say in the interview, please feel free to write to us. Once we have collected all the interview data from the various participants, we will analyse it and use the findings to develop the framework for integrating BIM into the curriculum. We will disseminate our approach through reports and journal papers and perhaps a public forum, to which you will be invited.

Finally, we would like to know if you would be interested in appearing in a video on this research. We will produce three videos which will showcase our approach. Your participation in any video is entirely voluntary. The exact topics and scripts will be decided at a later stage, once we have established the first outcomes of this study. At this point in time, we are only collecting expressions of interest. Would you be willing to, perhaps, participate in a video in which you could present your thoughts, experiences or opinions?

Thank you for your time and openness. I will now stop the recording.

Is there anything that you would like to add ‘off the record’?

1.12.2 Data sheet template for interviews with employers General data

Employer	Date

1. Could you, please, start by introducing yourself?			
Current position, for how long	Kind of company (CM, PM, Arch, Eng)	Size, national/ international company	Construction field; unique selling point

2. … current experiences with BIM?			
BIM used for how long, Why	How and to what extent	Type of projects, stages	BIM in international projects
Transformation in thinking through BIM		Challenges around BIM and how they were overcome	

Industry perspective	Attitude towards BIM	Attitude towards BIM education

Keywords	Word repetitions	'Indigenous categories'	Metaphors and analogies
Key phrases			

1.12.3 Experience with BIM

Employer	Date

3. Reflection on current state of knowledge of BIM of graduates

Expected skills & knowledge	How were expectation met	BIM training for employees	BIM skills particularly relevant in globalised industry

4. Globalisation of industry & Internationalisation of curriculum

Challenges	Positive outcomes - added value	
o challenges and ways to overcome them	o "work ready" o "global in outlook and competence" o "environmentally aware and responsible" o "culturally and socially aware" o "active and lifelong learners" o "innovative" **o Student mobility** **o Research**	o "apply knowledge of theory to practice" o "Professional communication" o "Formulate evidence based solutions" o "independent and collaborative learning" o "Critically reflect on profession local and global context"

5. Threshold diagram discussion	
Response to Integrated Model	Topics
o embedded model vs streamlined vs add-on o themes - missing, to be changed o level approach (cognition, compatibility, connectivity) o Capstone (learning to lead)	o clarification o challenges o positive aspects
Ideal teaching/ delivery methods	**6. Additional information**
o interdisciplinary teaching o real life projects o work integrated learning o	EOI in video Yes ◯ No ◯

2 Dissemination strategies and outputs

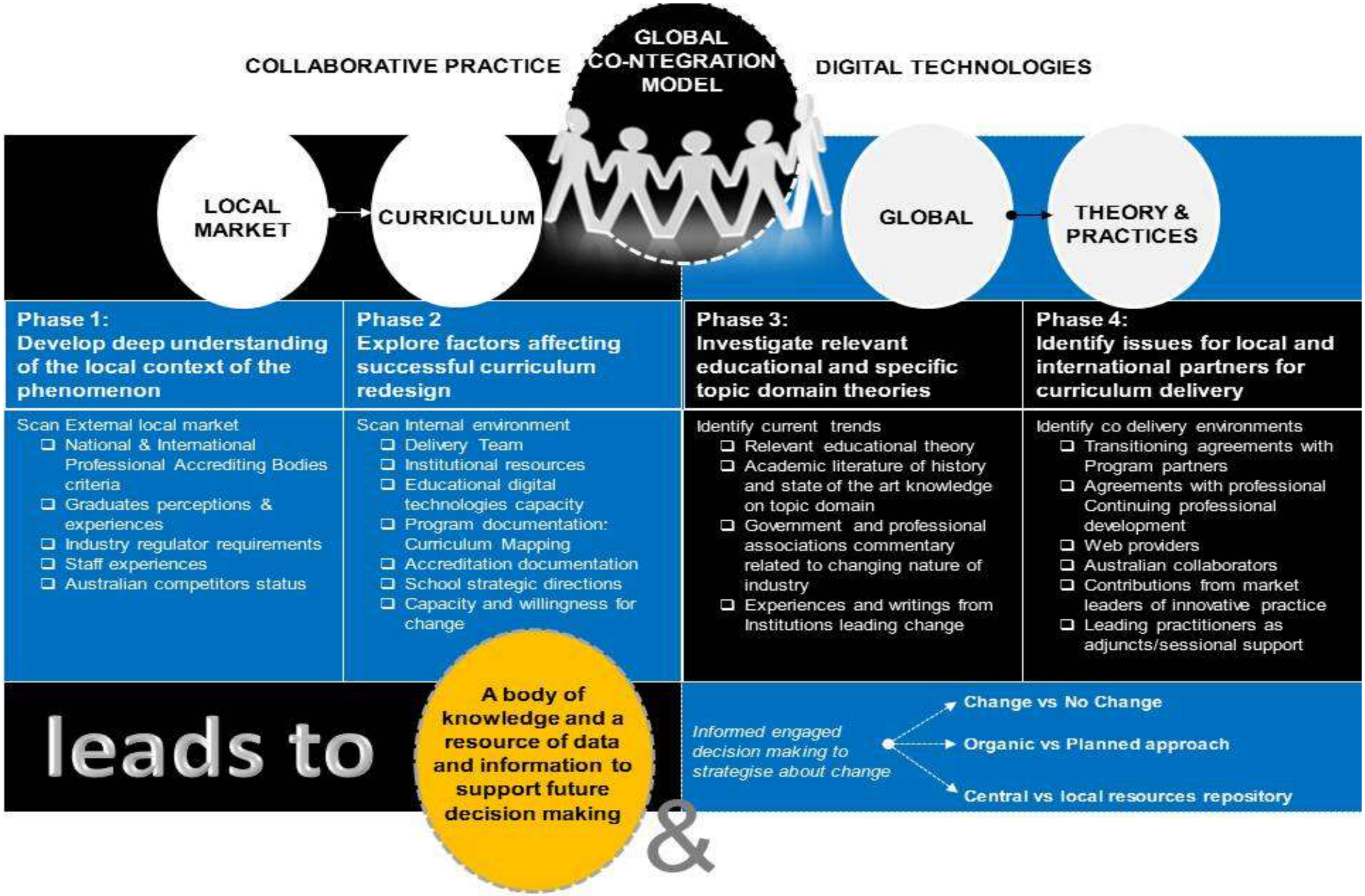
Activity	Timeframe
Presentation of project to School of PCPM Program Delivery Team meetings	Mar – May 2015
Presentation/Summary Report to Professional Accrediting Bodies.	Jul – Aug 2015
Circulation of Summary Report Brochure to Project Steering Committee	Jul –Aug 2015
Circulation of report to project participants.	Apr 2015
Report uploaded to the Centre of Integrated Project Solutions website	Apr 2015
Academic publications: London, K. Maqsood,T. Wong,P. Khalfan,M. & Willand,N. (2015) The Challenge for Australia in BIM Education for Construction, *Australasian Journal of Construction Economics and Building (in preparation)*	Submit Sep 2015 and Publish Mar 2016 (anticipated)
London, K. Maqsood,T. Wong,P. Khalfan,M. & Willand,N. (2016) A Risk Averse approach to the Development of an undergraduate Student Threshold Capability Framework for Digital Construction Management within a Global Co-integration Model, Chapter 22 in Minimising Risk in the Building Information Modelling environment : applied research and innovative practice, Editor London,K. Taylor and Frances, Wileys, UK. *(in preparation)*	Publish Mar 2016

3 Evaluation of project outcomes

Stage	Evaluation Tasks descriptions	Evaluative commentary
I	Literature sourcing and review and Ethics Application Ongoing Report literature review outcome and complete ethic application to inform interim evaluation report project evaluation Prepare interim evaluation report of Stage 1 by the end of Month 3. Review progress of project and evaluation plan	During this phase the team were in constant email discussions in relation to the Ethics application. At times the reviewing was done by all members and in future this could be tasked to the Project Leader and one other member for efficiency. One team member suggested that there was too much reviewing. This is useful feedback and provides insights. However the Project Leader ultimately believes it is a useful tactic for all Investigators on the application to be actively involved in reviewing as they each sign off on the project. It is also useful to ensure that all team members know what the project is about and are engaged and contribute. Feedback was on occasions not timely. There was less feedback provided by the team members on the literature review drafts. They were well written as drafts. The Project Leader edited and restructured material for the final report. Very little editing was required in the BIM in Education section however significant editing and restructuring was required in the Educational theory section. This was anticipated. The BIM Education literature review and Ethics application were completed on time to inform the interim evaluation report. The Education review was not fully completed. This did not pose a significant problem. The interim report was completed. We reviewed the progress of the project on a fortnightly basis during the project. The Project Leader was in China at the beginning of the year for a major Department of Industry Category 1 funded research grant and was not able to initiate the LTIF till end February. This delayed the start of the project and delayed recruitment of the Project Officer and thus delayed spending on the project. A revised Project Plan was developed and a revised strategy. (refer to stage 1)
2	Collect course information from the partners and map learning outcomes and graduate profiles. Modify and adapt the curriculum design aligned with literature and feedback from all stakeholders. Ongoing project evaluation (including monthly meetings with project team) Review all data gathered and analysed, and re-compare to project aims and objectives Prepare interim evaluation report of Stage 2 by the end of Month 8.	It was difficult to obtain program and course documentation ie. If we were able to obtain detailed program accreditation documents we would have been able to more efficiently map learning outcomes and graduate profiles. The program accreditation documentation still has not been provided for this project. This identified a problem in information storage in the School which in many ways is a positive as this has now been addressed. However it hindered our capacity to efficiently and effectively complete the mapping exercise we envisaged. We sought to overlap a map of what was taught in BIM in the program. However we had to develop documentation from first principles and then identify activities in relation to teaching BIM. It was also difficult to obtain the CAP documentation. There was no documentation provided until late September and yet we were seeking this documentation as early as February and therefore this was extremely challenging. The documentation was minimal. Our industry are often very difficult to pin down to interviews and meetings and so there were delays. We determined that for more effective and efficient analysis of the interview data we would ensure that the Project Leader, Project Officer and at least one other Team Member was present for each interview. A debriefing meeting and discussion on themes was conducted immediately after each session. This delayed organisation and logistics however efficiencies were gained in the final writing up. Contributions were made by all team members to the data analysis. We evaluated how to address these delays and developed the following strategy: ▪ Develop a theoretical model of the Threshold Capability Framework to present to stakeholders during discussion (originally we had intended on creating this through emergent thematic analysis) ▪ Focus on Phase 1 Curriculum Redesign ie analysis of context of change and how it impacts sustainable design and delivery of new curriculum ▪ Focus on extensive and detailed consultation with relevant stakeholders to ensure a complete understanding of local context was understood ▪ Development of additional and alternative digital resource materials to support staff The Project Leader and team members receive an extraordinary volume of email traffic on a daily basis and at times this was challenging and frustrating in relation to this project as there were times when staff did not respond to the Project Officer. A more coordinated approach to communications would be better in the future.
3	Design and produce online videos Ongoing project evaluation (including monthly meetings with project leaders) Prepare interim evaluation report of Stage 3 by the end of Month 10.	The delayed start impacted upon the production of the videos to some extent. However we are finalising editing of these and they are much more nuanced to the needs of the academic staff following advice from staff and past students. We presented the project to our Project Steering Committee twice during the year and had follow up individual meetings with 3 members. Their advice and guidance was well informed and was invaluable to the outcome of the project. Three of the members are market leaders in BIM implementation and understand the nature of this emerging phenomenon very well and provided excellent insights. We were also able to interview the UK leader in BIM Implementation in the Industry (who developed the strategy for the government) and also the Prof London visited and interviewed the UK Education Leader. Alongside this Associate Professor Maqsood's contact in Auburn University was invaluable as this provided us with an exemplary case study and identify significant lessons learned from their implementation. Auburn would more than likely be one of the international leaders in curriculum design and delivery and so their insights and contributions were very useful on this project.
4	Final report submission. Presentation Dissemination of results in publication Prepare summative evaluation report for the project	We are now able to obtain feedback on the completed report and this will enable an ongoing engagement with the stakeholders. Our industry will engage with the Infographics created (which is additional outcome) and an Industry Brochure summary of the project rather than the lengthy report however some of them will engage with the longer report as well. Feedback on the Infographic has been very positive. Some initial feedback has been obtained from the interviewees and Project Steering Committee on the Threshold Capability Framework. Without exception all have been positive on the concept of the Threshold Capability Framework and without exception the approach to include wider skills, knowledge and capabilities and not just technical skills has been met with extensive support. Advice and guidance has been provided and enhanced the outcome. One of the marker leaders (member of the Project Steering Committee) is involved in nationally funded collaborative research project and has expressed interest in us developing a Framework for the employees in their organisation. The next 3 months will involve presentations to staff and this will raise staff awareness of the project outcomes.


BIM
IN CONSTRUCTION EDUCATION
promotes
GLOBAL WORKING PRACTICES
&
COLLABORATION
creates
'SMART' CONSTRUCTION GRADUATES
The BIM Forest of Terminology
Where do we start?
using
SKILLS
THRESHOLD CAPABILITIES FRAMEWORK
DIGITAL TECHNOLOGIES FOR LEARNING
TECHNOLOGY
&
GLOBAL CO-NTEGRATION MODEL
BIM
Industry and educational LEADERSHIP
leads to
London et al 2015, RMIT University

Appendix A


COLLABORATIVE PRACTICE
GLOBAL CO-NTEGRATION MODEL
DIGITAL TECHNOLOGIES
LOCAL MARKET
CURRICULUM
GLOBAL
THEORY & PRACTICES
Phase 1: Develop deep understanding of the local context of the phenomenon
Phase 2 Explore factors affecting successful curriculum redesign
Phase 3: Investigate relevant educational and specific topic domain theories
Phase 4: Identify issues for local and international partners for curriculum delivery
Scan External local market
National & International Professional Accrediting Bodies criteria
Graduates perceptions & experiences
Industry regulator requirements
Staff experiences
Australian competitors status
Scan Internal environment
Delivery Team
Institutional resources
Educational digital technologies capacity
Program documentation: Curriculum Mapping
Accreditation documentation
School strategic directions
Capacity and willingness for change
Identify current trends
Relevant educational theory
Academic literature of history and state of the art knowledge on topic domain
Government and professional associations commentary related to changing nature of industry
Experiences and writings from Institutions leading change
Identify co delivery environments
Transitioning agreements with Program partners
Agreements with professional Continuing professional development
Web providers
Australian collaborators
Contributions from market leaders of innovative practice
Leading practitioners as adjuncts/sessional support
leads to
A body of knowledge and a resource of data and information to support future decision making
&
Informed engaged decision making to strategise about change
Change vs No Change
Organic vs Planned approach
Central vs local resources repository