BIM in Architectural Education
Preparation of Graduates for Future Industry Demands

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Abstract

Building Information Modelling (BIM) has changed the way the Architecture, Engineering and Construction and Building Operations (AECO) industry runs its day to day business. This in turn affects how universities prepare graduates to face industry demands. This paper attempts to demystify BIM and the competencies required for current AECO business practices. It also looks at possible future capabilities required based on the stages of BIM development and investment.

The author approaches the subject through desktop study and a series of surveys and interviews with fellow BIM practitioners. The paper attempts to link BIM skill sets and relevant core competencies required within several current national standards of competency for architects.

This paper is written based on personal observation from over a decade of teaching, practicing and managing BIM; it does not reflect the position or direction of current or past institutions where the author has been employed.

Keywords: Building Information Modelling, Architectural Education Core Competencies, BIM skill sets.

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1. What is Building Information Modelling?

The US National BIM Standard Project Committee defines BIM as follows:

"Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition." [1]

However, to the general public, the author has found that the easiest way to explain the difference between BIM and Legacy CAD is by the workflow of design from concept to completion.

- Legacy CAD

  Traditional CAD is like traditional pen and paper documentation. It is merely a digital drawing board, so generally the workflow is:

  3D concept in the designers head represented in 2D documentation to be passed on to the builder on site for his interpretation to construct in 3D.

  Traditionally a set of documentation is accompanied by specifications and proprietary installation manuals to assist the builder in understanding the design intent.

- BIM

  BIM enables the designer (architects and engineers) to document and design directly in 3D and pass on the design intent to the builder on site both in traditional 2D and a hybrid 3D model that contains metadata, parameters and specification information.

  This removes the need and risk for the builder to guess the design's spatial layout based on flat 2D drawings.

  BIM also enables cross disciplinary collaboration and design coordination between the architect and its engineering consultants. BIM even goes beyond construction and assists the owner in asset maintenance and operational planning, and even demolition.

There are many misconceptions of BIM, commonly known as 'BIM wash', which has arisen from years of sales pitching by industry managers in order to gain traction in the implementation of BIM. Unfortunately this also results in some institutions feeling burnt and disappointed while following the steep learning curve of BIM implementation.

[1] *http://www.nationalbimstandard.org/faq.php#faq1* The US National BIM Standard Project Committee.

2. Why should the AECO industry embrace BIM?

[2]Yusuf (2014) in his recent study identified the emergence of BIM as a result of inefficiencies in the Architectural, Engineering and Construction (AEC) industry. Inefficiencies have been widely reported and can be attributed to the pressure within the industry to provide better value for money and better efficiency in product delivery. It is apparent that this pressure is reflected in the UK government's target to reduce reduce the cost of public sector construction by 15-20% by the end of 2015. Similarly, there is pressure from environmental regulatory requirements and societal demands for the delivery of greener products; challenging the AEC industry to decrease waste, adopt sustainable construction solutions and reduce carbon emissions. It is argued that better designs will play a pivotal role in enabling the AEC industry to meet these goals and the adoption of emerging and innovative technologies is central to this (HM Government, 2013 in Yusuf, 2014).

BIM can arguably be the 'logical solution' for improving the quality of designs by mitigating risks and discrepancies by enforcing all design elements to be simulated and coordinated within the one shared virtual environment.

BIM enforces information (data) integrity, therefore ensuring:

a) Synchronized data between various stake holders.
b) Automatic generation of drawings, reports, design analysis, schedule simulations, etc.
c) Eliminates data redundancy, data loss and mistranslation of data.

BIM enables an integrated project delivery that carries the benefit of:

- faster design authoring
- clash detection
- collaborative design coordination
- high adaptability to change
- opportunities for integrated scheduling, phasing, and costing
- information for asset management and operations planning.

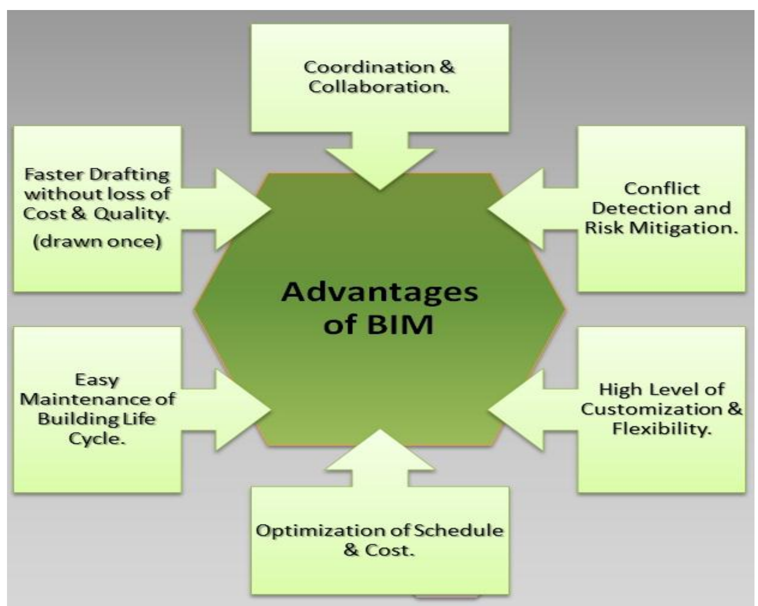

Figure 1 Advantages of BIM

[2] Jonah Kwatri Yusuf, 2014, Investigation into the adoption of Building Information Modelling (BIM) in Architectural SMEs in the United Kingdom

3. How does BIM fit in within architectural core competencies?

According to the UNESCO/UIA Charter for Architectural Education, 2001, architectural education has two basic purposes:

To produce competent, creative, critically minded and ethical professionals and designers/builders; to produce good world citizens who are intellectually mature, ecologically sensitive and socially responsible.[3]

And among its fundamental objectives for architectural education includes:

- *Ability to create architectural designs that satisfy both aesthetic and technical requirements..*
- *Understanding of the relationship between people and buildings, and between buildings and their environment, and of the need to relate buildings and the spaces between them to human needs and scale.*
- *Understanding of the methods of investigation and preparation of the brief for a design project.*
- *Understanding of the structural design, construction and engineering problems associated with building design.*
- *Adequate knowledge of physical problems and technologies and of the function of buildings so as to provide them with internal conditions of comfort and protection against the climate.*
- *Design skills necessary to meet building users' requirements within the constraints imposed by cost factors and building regulations.*
- *Adequate knowledge of the means of achieving ecologically responsible design and environmental conservation and rehabilitation.*
- *Development of a creative competence in building techniques, founded on a comprehensive understanding of the disciplines and construction methods related to architecture.*
- *Adequate knowledge of project financing, project management, cost control and methods of project delivery.*

The above objectives seem to be able to benefit from the capabilities of BIM technologies, as it supports the student/ practitioner to better understand these issues within its context.

The author also attempted to review several competency standards for architects from around the world. For this paper 3 examples are used, namely:

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[3] UNESCO/UIA Charter for Architectural Education, 2001

1. The Institut Arsitek Indonesia's 'Red Book' (2010) 'Guideline for Architect's Work Relations with Clients', which is the known guideline for minimum project deliverables and architect's rights and responsibilities.
2. The 'National Competency Standards in Architecture' (2009) from the Architect's Accreditation Council of Australia
3. The Korean Architectural Accrediting Board's 'Conditions and Procedures For Professional Degree Programs in Architecture' (2013)

Within the Red Book[4] the architect is required to deliver the following responsibilities, which BIM can assist:

Item (d.) Coordinate the design and planning with consultants and experts from other disciplines, whether that appointed by the client or the architect, to support the design process to achieve targets of quality, time and cost.

Item (f.) To conduct regular supervision and construction checks, so that construction is implemented as per design and planning drawings and the RKS - Requirements and Schedule of Works and applicable regulations.

The KAAB Student Performance Criteria[5] lists 30 core competencies preceding an Architecure Program Report defined under Communication, Design, Engineering/ Technology, Professional Practice. The following core competencies can benefit from BIM technologies:

02. Various means of expression;

09. Form and Spatial Organization; *Understanding of the basic principles of 2D and 3D forms and design, architectural composition and ability to apply these principles to design a building.*

10. Analysis and Programing

15. Integration of Building Systems in Design

16. Design of Addition/Alternation, Repair, and Maintenance

18. Integrated Design

19-20 Structural systems

21-22 Environmental control

23. Building services

[4] Institut Arsitek Indonesia's 'Red Book' (2010) 'Guideline for Architect's Work Relations with Clients'

[5] Korea Architectural Accrediting Board, KAAB Conditions & Procedures; For Professional Degree Programs in Architecture 2013 Edition

24. Application of Computer Technology ; *Understanding of the utilization and application of computer technology in the design process including, for instance, a building information modelling system.*

The KAAB Conditions & Procedures is probably the only architecture core competency guideline document that specifically mentions the term Building Information Modelling.

The NCSA (2009) defines four Units of Competency, which are: Design, Documentation, Project Management and Practice Management.

The following contexts within the competencies seem to be relevant and can benefit from BIM technologies:

Design- *To create an architectural design through the exercise of knowledge, imagination, judgement (sic) and professional responsibility.*

Documentation- *To generate documentation and clearly communicate information for an architectural project so that it can be costed (sic), built and completed in accordance with the brief, time frame, cost and quality objectives.*[6]

From these competency standards it is clear that the advantages of BIM can benefit architectural students and practitioners within the profession.

4. BIM Skill Sets

Bilal Succar from Change Agents, Australia in his seminar paper[7] in the Seminario Internacional BIM, Sao Paolo 2013 classified BIM performance into 3 categories: Managerial, Operations and Technical.

Managerial	Operational	Technical
1. General Management 2. Leadership 3. Strategic Planning 4. Organisational Management 5. Business Development and Client Management 6. Partnership and Alliancing	1. General model use 2. Capturing and Representing 3. Planning and Designing 4. Simulating and Quantifying 5. Construction and Fabricating 6. Operating and Maintaining	1. General IT 2. Software Systems 3. Hardware and Equipment 4. Modelling 5. Documentation 6. Presentation and Animation

[6] 'National Competency Standards in Architecture' (2009) Architect's Accreditation Council of Australia

[7] Bilal Succar (2013) The BIM Competencies of Industry Practitioners, Seminar Presentation, Change Agents, Australia

BIM is often described with stages of implementation based on content, from 1D to 6D. The author has attempted to match core BIM skill sets with the staging of BIM, as described in the following table:

[1D] PROJECT DEFINITION	[2D] DRAWINGS + SCHEDULES	[3D] COORDINATION MODEL
BASIS OF DESIGN + CONSTRUCTION	SCOPE, BOUNDARIES, REQUIREMENTS, + PLANNING	COLLABORATE + COORDINATE
UNDERSTANDING THE PROJECT BRIEF UNDERSTANDING FUNC-TIONALITIES REQUIRED	SPACIAL PROGRAMMING GETTING THE BALANCE RIGHT ZONING DESIGN AUTHORING INTER-DISCIPLINARY MUDMAPPING	SPATIAL STUDIES DESIGN MODELLING SITE ANALYSIS COLABORATIVE 3D DESIGN COORDINATION CLASH DETECTION STRUCTURAL ANALYSIS MEP ANALYSIS ESD ANALYSIS MODEL MANAGEMENT

These skill sets are mainly at technical/ operational level, of which requires at a manager's level some overarching skills including:

- BIM Model Management.
- BIM setup and planning.
- BIM model libraries: creation and document control.
- BIM Level of Development detail classification.
- BIM data management.
- BIM stakeholder management.

- Model auditing and revision control.

However, these skills are maybe more suitable for a dedicated BIM Manager/ Coordinator rather than the Architect.

5. Where, when and how do we implement BIM within architectural education?

Where

Current alternatives for BIM training often comprise of proprietary BIM authoring tools such as Revit™ and ArchiCAD™. These are often provided by Authorized Software Resellers/ Vendors and some even have Authorized Training Programs direct from the software manufacturers. As a result, these are often commercially driven and not directly catered to the needs of the architectural profession.

It would appear that the majority of BIM education available to date focuses on training in the use of particular BIM software packages. Training in openBIM concepts, BIM management and working in collaborative BIM environments, appears to still be in its infancy. Rooney (2013)[8]

There is an opportunity for campuses to integrate BIM education within the curriculum in order to equip the right skill sets that support the core competencies targeted by architectural education.

When

Various campuses have different approaches to the issue. Some are quite content in providing the skills and/or facilities to learn at an early stage. The argument is that BIM is nowadays a reality rather than a luxury, and students will endeavor to learn BIM even within their own means.

Other campuses feel that in order achieve the core competencies, the traditional method of eye to pencil to paper is crucial for the student to understand spatial representation. There is also the element of construction knowledge which can only be achieved through years of study, research and experience. Without these basic skills a student can merely model a building, without the benefit of BIM assisting in the understanding of constructability.

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[8] Kevin Rooney, 2013, BIM EDUCATION - GLOBAL - SUMMARY REPORT – 2013, ISSUE VERSION: V1.0

Given the simulated and collaborative nature of BIM, it provides a unique opportunity for students to work together within a virtual environment both with their peers and with students and professionals of other AEC disciplines.

How

The Australian Institute of Architects (AIA) and Consult Australia established a BIM education working group of industry and academia members in 2011[9].

The group identified 20 education principles (EP), the following are the key principles related to BIM learning providers:

- EP9. Accreditation and professional associations should engage with universities to develop new collaborative BIM courses or to integrate the principles and technologies of multidisciplinary collaboration into their existing curricula.

- EP11. There is need to de-mystify the BIM process and develop integrated, coordinated and viable BIM training modules delivered via professional associations. These training modules should align with university/TAFE curricula and tightly complement their educational deliverables.

- EP13. There is a need for regular BIM Learning opportunities and non-technical BIM learning materials, specifically tailored for senior and executive staff.

- EP14. There is a need to consider how to assess and improve the BIM knowledge, skill and experience of current professionals, para-professionals and tradespeople.

Interdisciplinary design workshops/ studios provide a good opportunity for students to interact with students of other disciplines to identify constructability issues and understand the full building design process.

Basic skills can be obtained by targeted electives, which cover the overview of BIM and basic to intermediate operational skills. A final design assignment with complex management issues should be able to provide initial ideas of the building information model management and strategies.

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[9] Richard Choy, 2013, BIM EDUCATION - GLOBAL - SUMMARY REPORT – 2013, ISSUE VERSION: V1.0

6. Where is industry currently at with BIM implementation?

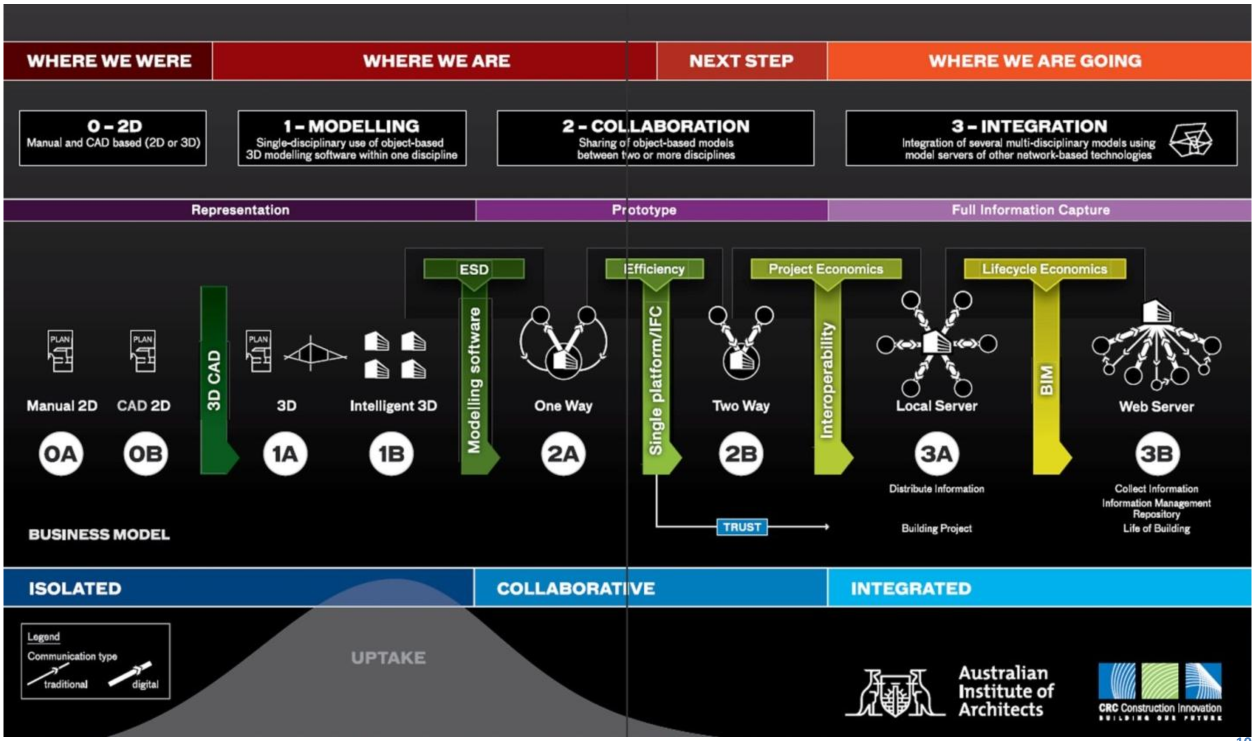

Figure 2 Current Stages of BIM Implementation [10]

The above figure shows the stages of BIM implementation as described by a joint study between Australian Institute of Architects and the Cooperative Research Centre - Construction Innovation.

This figure is widely adopted within Australia's BIM industry as the stages of which a company would want to aim for their project delivery. Currently, based on interviews and author's observation, most companies are at 2A which is One Way collaboration meaning the BIM model gets exported and feedback is returned traditionally; or 2B in which models are shared and integrated within a server/ integrated design coordination model.

In the author's most recent projects, due to instability of a BIM server, the project management team in most cases agree to utilise a project review software, which enables AEC teams to holistically review integrated models and data with stakeholders to gain better control over project outcomes. Integration, analysis and communication tools help the teams coordinate disciplines, resolve conflicts and plan projects before construction commences.

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[10] AIA, CRC-CI, 2009, National Building Information Modelling (BIM) Guidelines and Case Studies – Towards Integration Brochure

The *Towards Integration* diagram is arranged in four major stages, each with two minor stages referred to as 'levels'.

Stage 0 — 2D Documents

Level 0A: Manual 2D Drafting
Level 0B: CAD 2D Drafting

These two levels represent the traditional production of two-dimensional (2D) documents, primarily drawings. A large part of industry practice is still operating at this stage.

Stage 1 — Modelling

Level 1A: 3D CAD Modelling

3D CAD Modelling is the creation of three-dimensional (3D) geometry for improved visualisation. The building model objects have little or no data attached to them. Some of industry is operating at this stage.

Level 1B: Intelligent 3D Modelling

Intelligent 3D Modelling is the first stage in the adoption and use of BIM and most practitioners of BIM are at this stage.

A well-constructed model will reveal building issues that can be resolved immediately, rather than during the construction phases. This requires modelling procedures and standards, so that building model objects are created and connected in consistent ways.

Traditional views, drawings and documents can, if required, be automatically extracted and internally consistent, such as Automated 2D Plan, Sections, Elevations, Details, Schedules, Quantities, e-Specifications, 4D Construction Scheduling, 3D Visualisations, Perspectives, Sun studies, Animations, and Automated model checking.

Widespread industry capability at Level 1B can have a significant effect on the quality of project coordination and documentation.

Stage 2 — Collaboration

Level 2A: One-way Collaboration

In a one-way collaboration, the BIM model file can be exported to other participants for visualisation, coordination, communication, assessment, analysis, simulation or discipline design.

Feedback to the original discipline author for design and coordination would be in traditional formats and the original model is updated in digital isolation from other discipline models. For example, a structural engineer might export a model to the steel shop detailer/fabricator for detailed design and fabrication.

Coordination is required to select compatible file formats, versions, data structures etc. and the agreed formats make it easier for quality control and definition of responsibilities and ownership.

Level 2B: Two-way Collaboration

In a two-way collaboration, a common BIM model file data can be shared by two or more project participants in an iterative collaborative process which greatly enhances feedback and produces tighter integration of disciplines. A significant amount of coordination is required to establish compatible file formats, versions etc. and the correct selection of objects and their mapping settings.

A project could be made up of a number of discipline models, and in practice, might have some disciplines collaborating at different levels (e.g. architectural and structural at Level 2B and all other discipline collaboration at levels 1B or 2A).

Stage 3 — Integration

Levels 3A and 3B describe technologies and processes hosted on Model Servers and are considered in the CRC *Construction Innovation* Research Project 2007-03-EP Collaboration Platform Project — BIM Model Servers.

Figure 3 Explanation of stages[11]

Mandating of BIM, which is currently happening around the world will ensure that BIM investment and development will continue to improve along these stages. The following chart describes the level of application based on criteria and design stages for China, Hong Kong and Singapore compared to the world leaders Finland, Norway and USA.

Not surprisingly it shows that most are at the low end of the learning curve where confidence and adoption levels are quite low.

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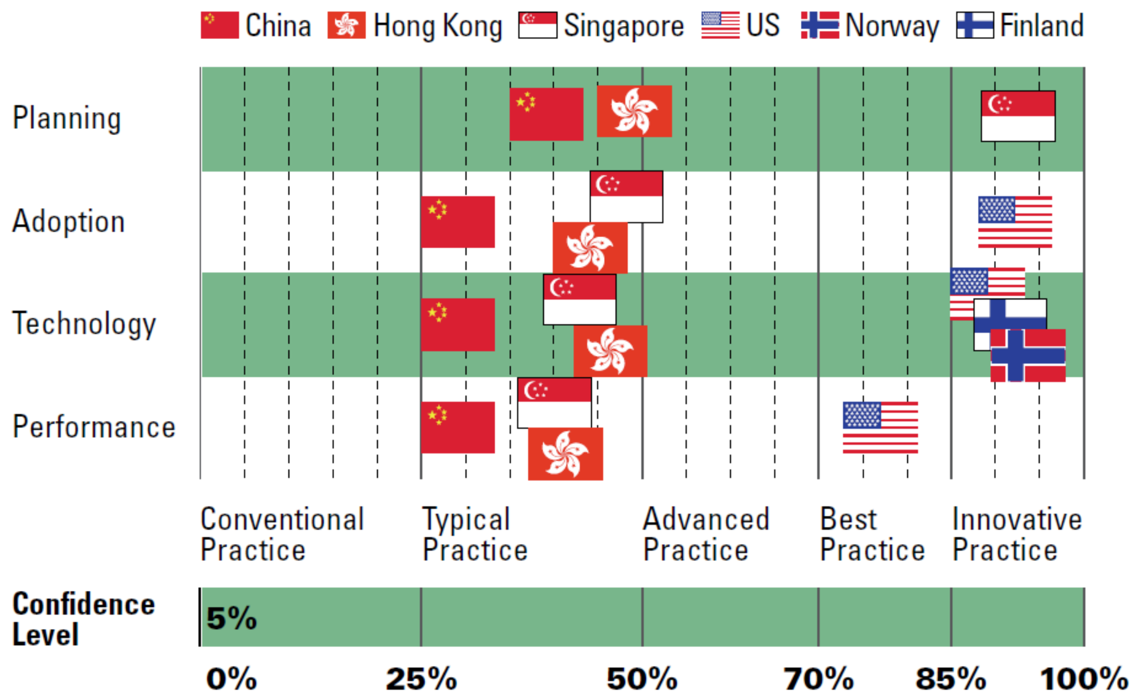
[11] AIA, CRC-CI, 2009, National Building Information Modelling (BIM) Guidelines and Case Studies – Towards Integration Brochure



Country to country comparison in terms of the four areas of BIM maturity: planning, adoption, technology and performance. Selected Asian economies—China, Singapore, and Hong Kong—are compared with countries leading in each of the four areas.

Figure 4 BIMscore for select Asian countries Compared to Leaders, SmartMarket report [12]

7. What are industry expectations for architectural graduates?

An industry reluctance to change, a 'wait and see' approach and a shortage of experienced/ educated BIM practitioners/ technicians/ educators is slowing the inevitable uptake of BIM in the AEC industry. It is clear that tertiary education institutions, with the support of government and industry, need to fully incorporate BIM education into their curricula, to provide the AEC industry with the 'BIM-ready' graduates required for the collaborative BIM working environments to which they will be part of in the future.[13]

BIM EDUCATION - GLOBAL - SUMMARY REPORT - 2013

From a few interviews with industry peers, when asked whether one would hire a graduate based on traditional architectural talents and capabilities or technical knowledge, surprisingly some prefer the talent as skills can be learnt. Also lack of skill can be perceived as a risk that could break a project workflow, resulting in companies willing to 'head hunt' industry proven

[12] McGraw Hill Construction – SmartMarket report 2014

[13] Richard Choy, 2013, BIM EDUCATION - GLOBAL - SUMMARY REPORT – 2013, ISSUE VERSION: V1.0

skilled professionals in the market. One would feel that this is quite unfortunate as companies would rather not invest in training of their graduates due to the fear that they would be poached by rival companies once a level of practical experience is reached.

This pushes the argument for graduates to be equipped with BIM skills from campus rather than spend valuable office hours learning the skills while potentially increasing risk to the project.

8. Conclusion

The author concludes that based on industry reports and academic studies, BIM is a beneficial skill for architectural graduates to have. There is strong potential for graduates to utilize BIM as a means to accelerate better understanding of how a building is put together.

BIM should not be seen as a substitute to traditional design documentation, rather an alternative that brings with it the benefits of virtually simulating a building design prior to construction. BIM complements core architectural competencies by providing a platform to gain construction knowledge at an earlier stage.

Students face a lot of competition in the job market once they graduate. BIM can act as a catalyst, or add value to their portfolios and kick start their careers.

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