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A REVIEW OF CURRICULUM DESIGN FOR BUILDING INFORMATION MODELLING.

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ABSTRACT

A study by Ahmed et al (2014) concluded that knowledge of health and safety regulations, interpreting contract documents, listening ability/ giving attention to details, knowledge of building codes and regulations, and time management are the five most important skills desirable in a new hire (*sic)* in construction management. Current literature and local research conducted with employers strongly indicates that skills associated with Building Information Modelling (BIM) will rank highly in skills demanded of future graduates in the built environment disciplines. The UK Government's Construction Strategy, 2011, mandates BIM implementation on all publicly procured projects, at level 2 by spring 2016. Learning outcomes were initially developed by the BIM Task Group to support the government's BIM strategy with the intention of releasing a formal BIM skills benchmark in spring 2013. The report entitled "Embedding Building Information Modelling (BIM) within the taught curriculum" by the HEA and BIM Academic Forum (BAF) was published towards the end of June 2013, providing a BIM teaching impact matrix, guidance on BIM maturity within courses and suggested Learning Outcomes at levels 4, 5 and 6. The Quantity Surveying (QS) programme at the authors' university developed some of the first BIM related modules within the School of the Built Environment and these were first delivered in the 2011-12 academic year. This study will review these BIM modules to evaluate their suitability for the QS curriculum and their application to industry using surveys of key stakeholders, primarily students, tutors and employers with the intention of developing a curriculum design for a standard module set that could be delivered across all courses associated with the built environment.

Keywords: BIM, curriculum, design, industry, HE.

INTRODUCTION

Building Information Modelling (BIM) is not new. The concept of BIM and nomenclature associated with BIM probably originated, in its crystallised form, from the work of Charles Eastman in the 1970's. (Eastman, 1975). However, recent developments in information and communications technology provide the facility for the effective and efficient realisation of the ideas. BIM has accelerated to prominence in the UK because in 2011, the Cabinet Office announced that as part of its new construction strategy, the Government's mandate was for the use of BIM at Level 2 on all public sector construction projects from April 2016. Then, on 11 February 2014, the EU Council approved two new EU Procurement Directives to replace the Utilities and Public Sector Directives. They came into force on 17 April 2014. The new EU Public Procurement Directive aims to encourage the use of BIM in public works.

CONTEXT

Building Information Modelling has been defined in many different ways. Sinclair (2014) gives a straightforward definition as:

> "BIM is the process of creating and managing information concerning a building, typically in a three-dimensional computer model which embeds data relating to its construction. If employed to its full extent, it is a tool used as part of the design process, throughout construction and for maintenance and alteration of the completed project."

David de Yarza, BIM Director of Lydig Construction Inc. asserted that BIM is "about a process, about a way to do things" (NBStv 2011). Hanna George, Associate, Norman Disney & Young, described BIM as a "digital representation of a building" using "structured information "that is co-ordinated" (NBStv 2011). Dr Stephen Hamill, Director of RIBA Enterprises offered the view that we should "…build it twice; once digitally and once physically. If you build it first digitally, then you know that it fits together properly" (NBStv 2011). Karl Redmond, Chief Executive of the Construction Sector Network defined BIM as "a collaborative tool". Koko Udom called for "greater collaboration" in a BIM legal discussion roundtable (NBStv 2013) while Peter Barker, Operations Director of the BIM Academy referred to construction as an "industry which is full of silos" and questions "why the industry doesn't collaborate more" (NBStv 2011). These three latter reflections of BIM are critical to the arguments put forward in this study because the position adopted for this study is that, finally, the construction industry has found a framework that requires collaborative working that should make it more effective and efficient. In parallel, Higher Education of the built environment disciplines has the technological tools and the policy framework underpinned by pedagogy, to advance collaborative learning that will embed in graduates those skills necessary for the international construction industry of the 21st century. Higher education of the disciplines associated with the built environment might be said to reflect these views of Peter Barker above because each discipline is, in general, educated at undergraduate level in isolation of the other disciplines; there is insufficient collaboration and / or interdisciplinary working. McGough et al (2013) in their paper that evaluated the integration of BIM in Higher Education using critical evaluation of the content of courses in Civil Engineering, Architecture and Building at their university, placed considerable emphasis on inter-disciplinarity, group-work, integration and collaboration. Nevertheless, in curriculum design and delivery, there is little collaboration within University institutions amongst architecture students, quantity surveying students, architectural technology students, civil engineering students, planning students, and so on. There is little collaboration amongst students in different institutions. This is at a time when there are a variety of radical advances in changing the nature of higher education in terms of learning spaces, curriculum, delivery, and the learning, teaching and assessment regimes. The rapid advances in digital technology facilitate and require such changes. When recently explaining BIM to a cohort of students, the tutor was slightly taken aback by the lack of surprise or wonder from students and accompanying comments such as: "well how else would you do it…". Construction management is significantly directed by procurement systems and contractual arrangements. Current procurement systems and contractual arrangements are not suited for optimising the potential benefits of BIM. For example, for the construction phase, JCT, NEC3 and other popular suites of standard form contracts purport to induce collaboration through the use of contract terms that, for example, require parties to act in "… a spirit of mutual trust and cooperation" (NEC3

Clause 10.1) or "…in a co-operative and collaborative manner…" (JCT SBC/Q Schedule 8, provision 1), these current contractual arrangements imply blame allocation by placing individual contractual responsibilities on all parties involved in the construction project. BIM is a catalyst for collaboration. A procurement strategy and contractual arrangement that accommodates collaboration from inception to completion and usage is yet to be devised for the BIM environment. This research recognises a parallel between a strategy for BIM and a strategy for BIM higher education in the built environment disciplines. A study by Ahmed et al (2014), that investigated the most important skills that today's construction industry requires from graduating construction management students, concluded that knowledge of health and safety regulations, interpreting contract documents, listening ability/ giving attention to details, knowledge of building codes and regulations, and time management are the five most important skills desirable in a new hire (sic) in construction management. Current literature and local research conducted with employers strongly indicates that skills associated with Building Information Modelling (BIM) will rank highly in skills demanded of future graduates in the built environment disciplines. These indications add weight to research undertaken Eadie et al. (2014) which demonstrated a consistent demand from construction related professional practitioners (multiple disciplines) for BIM to be taught in collaboration with other built environment programmes, with a strong 'context' (McLernon, 2006) and a suitably robust learning, teaching and assessment régime (McLernon, 2010).

THE STUDY

Learning outcomes for BIM were initially developed by the BIM Task Group to support the government's BIM strategy with the intention of releasing a formal BIM skills benchmark in spring 2013. The report entitled "Embedding Building Information Modelling (BIM) within the taught curriculum" by the HEA and BAF was published towards the end of June 2013, providing a BIM teaching impact matrix, guidance on BIM maturity within courses and suggested Learning Outcomes at levels 4, 5 and 6. The QS programme at the authors' university developed some of the first BIM related modules within the School of the Built Environment and these were first delivered in the 2011-12 academic year. The aim of this study is to review the content of BIM modules in a United Kingdom context to evaluate their suitability for the QS curriculum and their application to industry using surveys of key stakeholders, primarily students, tutors and employers with the intention of developing a curriculum design for a standard module set that could be delivered across all courses associated with the built environment.

Methodology

The following stakeholders were identified as having an interest in the content and structure of multi-cohort interdisciplinary BIM teaching in Higher Education establishments generally and at Ulster University specifically: Regular local employers (placement and graduate), NI BIM Hub representatives, and other collaborating companies. University teaching staff from the various construction related programmes within the Faculty of Art, Design and Built Environment (Architectural Technology, Architecture, Civil and Construction Engineering, Housing Management and Property Investment, Planning, Services Engineering and Surveying) were also invited to respond. To complete the sample, student groups from final year cohorts who have already benefitted from BIM education in some part of their programme, top BIM software vendors and BIM Task Group members were also invited to respond. Primary data was sought through responses to an electronic questionnaire using the Limesurvey™ Platform. This consists of a PHP administration area linked to a MYSQL™ database. In total 427 invitations were distributed. One Hundred and forty four (144) completed and 63 partially completed responses were received. In addition, 51 chose to opt out of doing the survey resulting in 258 responses in total resulting in a 60.4% response rate deemed very good for analysis by Rubin and Babbie (2009). To ascertain the suitability of the BIM modules included in the QS programme, questions were framed around the structure of a degree module designed for each year of an undergraduate programme. The HEA and BAF proposed Learning Outcomes (2013) for levels 4, 5 and 6 were used to frame the content of each module; however they were also informed by the BIM Task Groups revised draft Learning Outcome Framework (LOF). A mapping exercise between the proposed module content and the LOF was carried out to ensure comprehensive coverage. As a result the questions in each proposed module were similar in structure, but differed in proposed content. A pilot study was undertaken by forwarding draft questionnaires to some of the key stakeholders. Feedback from these initial drafts was used to redesign some question response formats and wording. The first part of the questionnaire was designed to ascertain the stakeholder group, experience in practice and experience and knowledge of BIM. The next three main sections outlined a framework designed to test the applicability of the proposed content to a BIM module and determine the resources that should be dedicated to these BIM modules entitled "*BIM Basics*" (Level 4 i.e. Year 1), "*BIM Implementation*" (Level 5 i.e. Year 2) and "*BIM Evaluation*" (Level 6 i.e. Final Year). Initially, questions sought to specifically affirm a previous study's conclusion that BIM should be taught in interdisciplinary cohorts and should include both theory and practice. The question also explored which vocational programmes should be included within the collaborative approach. The previous study had not considered it's applicability in each year of an undergraduate programme, or sought opinion on the breadth of collaboration, so conclusions were of a general nature. The next section listed the main content proposed to fit the LOF described above with response options of "*In BIM specific module*", "*Not BIM Specific*", "*In Year X*", "*In Year Y*". This structure of questions was repeated for each year of an undergraduate programme. The results from the survey would be correlated to determine trends and common ground within and between vocations / disciplines and compare the concluding modules with those developed by the QS programme in 2010/11.

STUDY FINDINGS

Statistics from the analysed responses are presented in Tables 1-3. The preferred option is bolded and italicised for the responses to every question. Table 1 indicates that all taught options were considered to be in the "*Theory only"* or "*Both"* theory and practice categories. The lack of preference for "*Neither"* in the responses indicates that all the chosen options were considered relevant. The lack of "*Practice only"* choices indicates the pedagogical importance of theoretical knowledge prior to practice. This is recognised by all respondents. Table 2 shows that the preferred size for the first year module is 10 credits with 20 credit points being the preferred size for other years. This suggests 100 hours input in first year and 200 hours input in the final two years. Table 3 indicates that the years chosen during the mapping were correct.

TABLE 1 Content

Year 1 Content	Theory Only	Practice Only	Both	Neither
Importance of collaboration	31.25%	2.78%	***65.97%***	0.00%
The business of BIM	***52.78%***	2.78%	40.97%	3.47%
Introduction to technology used across disciplines	12.50%	11.81%	***75.69%***	0.00%
BIM as a process/technology/ people/policy	18.06%	4.17%	***76.39%***	1.39%
Year 2 Content	**Theory Only**	**Practice Only**	**Both**	**Neither**
BIM concepts – construction processes	40.28%	6.25%	***53.47%***	0.00%
Stakeholders' business drivers	***69.44%***	6.25%	18.06%	6.25%
Supply chain integration	***59.72%***	6.25%	31.25%	2.78%
Use of visual representations	11.11%	25.00%	***63.89%***	0.00%
BIM tools and applications	2.78%	28.47%	***68.75%***	0.00%
Attributes of a BIM system	27.78%	16.67%	***55.56%***	0.00%
Value, lifecycle and sustainability	***49.31%***	7.64%	42.36%	0.69%
Software as service' platforms for projects	18.75%	22.22%	***56.25%***	2.78%
Collaborative working	11.81%	19.44%	***65.97%***	2.78%
Communication within inter-disciplinary teams	15.97%	13.89%	***67.36%***	2.78%
Year 3 Content	**Theory Only**	**Practice Only**	**Both**	**Neither**
BIM across the disciplines	39.58%	6.94%	***53.47%***	0.00%
Contractual and legal frameworks/regulation	***59.03%***	3.47%	36.11%	1.39%
People/change management	***59.72%***	2.08%	36.11%	2.08%
Technical knowhow Structures and materials	27.78%	11.81%	***59.72%***	0.69%
Technical knowhow Sustainability	37.50%	10.42%	***50.69%***	1.39%
Process/management: How to deliver projects using BIM	13.19%	12.50%	***73.61%***	0.69%
Process/management: Information and data flows	25.00%	12.50%	***62.50%***	0.00%
Process/management: BIM protocols/EIR	33.3%	9.03%	***56.94%***	0.69%

Table 2 Credit Points

Year 1 Credit Points (%)				
5	***10***	15	20	Over 20
8	***50***	4	38	0
Year 2 Credit Points (%)				
5	10	15	***20***	Over 20
4	33	13	***50***	0
Final Year Credit Points (%)				
5	10	15	***20***	Over 20
4	33	13	***46***	4

TABLE 3 Combinations Legend A= In specific BIM module, B = In other 1st Yr Modules, C = In Year 2, D = In Year 4 and E= Not BIM Related Teaching

Year 1 Combinations	A %	B %	C %	D %	E %
Identifying and describing traditional Design Documentation (i.e. plans / elevations / sections / details / perspectives / isometric) and workflow associated with drafting.	32.6	***54.9***	6.2	2.8	3.5
Typical construction Supply Chain (organisational, communication and contractual structures, roles and responsibilities)	25.0	***39.6***	19.4	7.0	9.0
Digital Plan of Works + mapping to Professional Body and other Plan of Works / Building Life Cycle / client decision points	***41.0***	16.7	30.5	10.4	1.4
Traditional collaboration / barriers to collaboration within design teams / supply chain	***33.3***	22.2	30.6	9.7	4.2
Government reports such as Egan, Latham etc.	15.3	***26.4***	18.7	25.7	13.9
Drivers for BIM / Construction Strategy	***54.9***	18.7	13.9	12.5	0.0
Introduction to BIM process, Maturity Levels (Project & Organisational), Standards.	***66.7***	14.6	12.5	6.2	0.0
Technology enabling BIM (i.e. Laser Scans / GPS / drones / web-based hosting / secure file transfer protocols / hardware & software requirements / mobile apps / augmented reality)	***57.6***	9.0	19.5	13.9	0.0

People's resistance to change / attitudes / change management	***31.2***	***31.2***	13.2	16.7	7.7
Standards (BS1192 + PAS1192)	***38.2***	17.4	22.2	14.6	7.6
2D Drafting of basic documents i.e. plans and elevations.	34.7	***43.8***	11.1	4.9	5.6
3D Modelling	***43.7***	13.2	27.1	14.6	1.4
Year 2 Combinations	**A %**	**B %**	**C %**	**D %**	**E %**
BIM drivers, CAPEX / OPEX, Soft Landings	***70.1***	15.3	5.6	6.9	2.1
Benefits of BIM for different procurement options (traditional, D&B, Negotiated etc.)	***49.3***	28.5	6.9	11.8	3.5
Benefits of Integrated Project Delivery (Toyota principles, comparisons with automotive, retail sectors etc.)	***37.5***	31.9	9.7	13.2	7.6
BIM Roles (BIM Execution Plans, Information Management, Task Managers, Task Teams etc.)	***61.1***	18.1	9.0	11.1	0.7
Virtual Design & Construct (VDC)	***54.2***	25.0	8.3	10.4	2.1
BIM uses for design (visualisation, walkthroughs, decision making, level of detail, cost & programme transparency)	***65.3***	18.1	7.6	9.0	0.0
BIM uses for construction management (clash detection, supply chain management, collaboration, Revision Comparison, Requests for Information, Health & Safety, O&M, etc.)	***59.1***	19.4	6.9	14.6	0.0
Dimensions of BIM (3D, 4D, 5D, 6D, nD)	***68.1***	13.9	5.6	11.1	1.4
Parametric Attributes of model objects / customisation of data fields / data in / data out.	***50.7***	25.7	9.7	13.2	0.7
Building SMART / Open BIM - Towards Level 3 and beyond	***55.5***	13.9	4.2	25.0	1.4
IFC and other model transfer formats & their limitations	***47.9***	19.4	7.7	19.4	5.6
Collaboration Tools	***50.0***	25.7	11.8	9.7	2.8
Common Data Environment	***53.5***	21.5	7.6	10.4	6.9
4D construction sequencing	***52.1***	16.7	2.8	22.9	5.5
5D QTO / Estimating, Clash Detection / Reports, Animations	***50.7***	12.5	2.8	27.8	6.2
Final Year Combinations	**A %**	**B %**	**C %**	**D %**	**E %**
Productivity improvements from BIM (Clients / AM/FM / Architects / Engineers / Surveyors / Clients / Suppliers / Contractors)	***71.6***	14.6	6.2	6.2	1.4
Service diversification as a result of BIM (Clients / AM/FM / Architects / Engineers / Surveyors / Clients / Suppliers / Contractors)	***63.9***	20.8	2.1	11.8	1.4
BIM Case study evidence from early adopters (Clients / AM/FM / Architects / Engineers / Surveyors / Clients / Suppliers / Contractors)	***61.8***	16.7	7.6	9.7	4.2
BIM Roles (BIM Execution Plans, Roles, Responsibilities, Zoning Strategy, Federation, Deliverables, Data Drops)	***61.1***	18.1	7.6	11.1	2.1
Big Data – informing design – evidence based design	***50.7***	26.4	4.9	11.8	6.2
Sustainable Construction Principles + Carbon Targets + demands for natural resources / LEAN Principles (war on waste)	33.3	***41.7***	10.4	8.3	6.3
Change Management theory / principles	32.7	***43.8***	6.9	6.9	9.7
BIM Protocol / implementation within existing forms of contract / Model Delivery Plan / Employers Information Requirements	***63.2***	21.5	4.2	8.3	2.8
COBie structures and families / templates	***57.6***	25.0	6.3	6.9	4.2
BIM Data maturity principles	***67.4***	13.9	4.9	11.8	2.0
PAS1192:3 Asset Information Modelling – keeping the model up to date during FM / Occupation.	***59.7***	24.3	4.9	9.0	2.1
Collaboration Tools - Adding specifications, technical booklets, O&M information into data fields for Assemblies, Elements and Materials	***61.1***	24.3	2.8	10.4	1.4
Common Data Environment - Adding U-Values / Carbon Footprint data into model components	***56.2***	26.4	4.2	9.0	4.2
Accessing data for de-construction using a variety of tools depending on vocational route	***56.9***	26.4	2.1	8.3	6.3

Only two options were chosen in Table 3 as responses: In *BIM Specific Module* or *In other year X modules* where year X was a similar year. However, five of the twelve first year attributes were considered complimentary to, rather than part of any specific BIM module namely: *Identifying and describing traditional Design Documentation and workflow associated with drafting and 2D Drafting of basic documents i.e. plans and elevations* (currently included within the 1st year QS BIM module), the *Typical construction Supply Chain, Government reports, People's resistance to change / attitudes / change management (currently taught in a complimentary 1st year QS module).* The removal of this material possibly contributes to the preferred 10 credit point value of the first year module. All of the second year contents were considered to be part of the second year BIM specific module. Only a fraction of this is included in the original QS BIM modules, which focuses on the file naming conventions and practical use of 5D Quantity Take Off tools and 4D Construction Simulation tools. It also includes some collaboration tools for RFIs on saved views. The final year responses indicated two of the fourteen final year attributes were considered complimentary to, rather than part of any specific BIM module namely: *Sustainable Construction Principles + Carbon Targets + demands for natural resources / LEAN Principles (war on waste)* and *Change Management theory / principles.* The current BIM content within the existing QS programme includes some of this content i.e. BIM Protocols and BIM Roles; the curriculum will need to be extended to accommodate the sections not currently covered.

CONCLUSIONS

This paper (as part of a longitudinal study) uses empirical data from a range of respondents to compile undergraduate curriculum content for BIM teaching with statistical backing for the first time. The study found that the BIM content of the existing modules within the QS programme requires alteration to accommodate the findings of this study. Tables 1 and 3 show the content of the proposed new modules and whether the content should be taught as theory only or theory and practice. The Tables further indicate whether specific content should be taught in BIM specific modules or other modules from similar years. The preferred module size for the first year module is 10 credits (100 hours student effort) with 20 credit points (200 hours student effort) being the preferred size for other years. This needs a change of course structures to accommodate this and further work is needed to see how this is carried out.

This paper is based on an initial analysis of the data collected. It is expected that these data together with additional data from further work on collaboration between courses will lead to a holistic view of curriculum and pedagogy relating to BIM modules in the Built Environment.

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