EMBEDDING BUILDING INFORMATION MODELLING (BIM) INTO CONSTRUCTION SYSTEMS 1 AND OTHER MODULES OF THE UNITEC NATIONAL DIPLOMA. (Architectural Technology-AT, Construction Management-CM, Quantity Surveying-QS)

ABSTRACT

The aim of this research was to generate a resource to assist construction lecturers in identifying opportunities where BIM could be employed to augment the delivery of course content within individual papers on Construction Technology programmes. The methodology involved detailed analysis of the learning objectives and underpinning knowledge of the course content topic areas within the residential Construction Systems 1 paper presently delivered at Unitec on the National Diploma AT, CM, QS tertiary programmes. The objective is to aid student understanding of specific aspects such as planning controls or sub-floor framing by using BIM models and, show how these can be used to enhance delivery using image, animation, and interactive student activity. A framework maps the BIM teaching opportunities against each topic area highlighting where these could be embedded into construction course delivery. This template also records software options and could be used in similar analyses of other course modules to assist with embedding BIM in course delivery.

Keywords: BIM embedding, Construction Technology, Tertiary courses.

INTRODUCTION

The purpose of this research paper is to investigate how Building Information Modelling (BIM) can be used to enrich a student’s learning experience and help bridge the gaps in understanding encountered when teaching students the more difficult concepts of Construction technology and design. The research is mainly a case study of a module, Construction Systems 1, delivered as part of the first year provision on the National Diploma programme at Unitec.

The embedding of ICT (Information and Communication Technology) and ILT (Information and Learning Technology) into
our learning landscape is something which most teachers would almost take for granted at the present time but it is a relatively recent development gaining momentum from the late 1990s onwards. Most lecturers would find it hard to imagine having to engage students now without employing the usual suspects of Word, Excel or PowerPoint but in the early days teachers were sometimes given incentives to buy into providing knowledge to their students using innovative new technologies.

Recent developments in the Built Environment sector, including the rapid evolution of BIM software across almost all traditional design team disciplines, already make a very strong case for utilising BIM innovations in teaching.

This research will demonstrate how integrating BIM models into teaching delivery can enhance student engagement and help communicate the more esoteric and tricky concepts which students find difficult to comprehend.

Building Information Modelling (BIM) involves creating digital models of buildings with Computer Aided Design (CAD) software which can then be used to extract a wide variety of information including data such as the following -:

- Visual data for design appraisal (3D BIM)
- Information take off figures to allow assessment of quantities and costs (5D BIM)
- Information to enable contract programming and management(4D BIM)
- Ability to check models for clash detection between for example structure and services (3D BIM)
- Model checking to see that all walls, floors and ceilings actually contain the spaces they are supposed to and within the correct dimensions. (3D BIM)
- Check building models against specific rules sets such as Fire regulations (3D BIM)

Definitions of 4D and 5D BIM vary but typically 4D BIM refers to model data used to produce sequencing and scheduling information whereas 5D BIM concerns estimations of building costs.
BIM can be sophisticated therefore and throw up some difficult concepts for students beginning their academic journeys especially. As the paper Construction Systems 1 on which this research is based occurs at an early stage of the National Diploma course overall, the examples presented weigh more towards the 3D.

Online rummaging to locate material applicable to my research revealed quite a lot of BIM documents but none quite aligned with my approach. This UK report came closest to my intentions.

**Embedding Building Information Modelling (BIM) within the taught curriculum. The Higher Education Academy, BIM Academic Forum. United Kingdom. June 2013.**

Resulting from a UK and Ireland institution’s workshop to respond to the ever changing built environment BIM scene and its’ impact on teaching, some correlations with my aims are highlighted below.

![Figure 1. BIM teaching impact matrix (Source: Higher Education Academy. United Kingdom)](image)

<table>
<thead>
<tr>
<th>BIM descriptor</th>
<th>Absent</th>
<th>Aware</th>
<th>Infused</th>
<th>Embedded</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BIM descriptor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIM is a nice research area but should not affect what and how we teach. Our students do not need to know about BIM.</td>
<td></td>
<td></td>
<td>Students should understand how BIM will affect their future and have chance to learn BIM in a discipline &amp; multi-disciplinary context.</td>
<td>BIM is so important it should become the vehicle for our students’ learning experience. Teaching should be enabled by the BIM model.</td>
</tr>
<tr>
<td>Curriculum</td>
<td>No change</td>
<td>Key modules are identified and BIM knowledge incorporated.</td>
<td>Target modules identified for a BIM review. BIM impact identified in all areas of the curriculum but BIM use restricted to a few.</td>
<td>Full curriculum review to allow every module to identify changes required for delivery through a BIM model.</td>
</tr>
<tr>
<td>Structure</td>
<td>No change</td>
<td>No change</td>
<td>Structural review needed but impact on current structure likely to be minimal.</td>
<td>A complete review of structure to enable the BIM model to be the driver for learning.</td>
</tr>
<tr>
<td>Staff</td>
<td>No change</td>
<td>Staff in the key modules will need an understanding of BIM and how it impacts of industry.</td>
<td>All staff require knowledge of BIM and how it is impacting industry. Some staff need full competence in use of BIM.</td>
<td>All staff would need to be fully competent in the use of BIM and understand how BIM is impacting on the industry.</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>No change</td>
<td>No change</td>
<td>Significant investment required. BIM labs needed and some delivery space suitable for BIM enabled learning.</td>
<td>Significant investment in infrastructure required. BIM labs and delivery space sufficient for BIM being the learning vehicle.</td>
</tr>
<tr>
<td>Curriculum - Research gap</td>
<td>Can be large</td>
<td>No change</td>
<td>Has to be small in some areas but with some flexibility.</td>
<td>Has to be small for all areas of the curriculum. Genuine integrated direction between research and curriculum delivery.</td>
</tr>
</tbody>
</table>

(William and Lees, 2009)
This body identified BIM concept related learning outcomes within current courses whereas I examined how to identify and use in an optimum way the outputs of BIM software in its’ various forms. The intention being to show how these can enhance and improve our teaching whilst helping bridge learning gaps that students presently struggle with. Hopefully by embedding BIM outputs more in our delivery, its’ use may become something that is part of the mindset of construction education and not seen as a bolt-on afterthought.

The methodologies involved in this research project were -:

1. Student survey of a first year Construction Systems 1(CS1) stream
2. Discussion with lecturers on the CS 1 paper and others who have generated BIM models as teaching resources.
3. A curriculum review of the CS 1 module to identify which topic areas provide potential to utilise BIM technologies.
4. Individual analysis of topic areas from CS1 to show how BIM methods may be effectively used to help student learning.

**Student stream survey comments and results.**
A small survey was given to a first year CS 1 cohort who had experience of viewing models both real and virtual in their first semester. To isolate key words and opinions I gathered up all the student’s responses and comments to create a Wordle cloud.

*Figure 2 - Word cloud from student responses (Source: Wordle)*

From the cloud it can be clearly seen that the words understanding, models, model, better, understand, appear to jump out with others such as building, different and real. This result would support my own personal observations of the areas where students need most support in the actual comprehension of
concepts and how actual building elements and components go together.

Discussion with lecturers on the CS1 paper and others who have generated virtual BIM models as teaching resources.

A number of informal exchanges were held with colleagues who teach on the multi stream CS1 module and complimentary papers in Studio 1. Some had developed their own BIM models for buildings of varying scales and I was keen to find out their primary reasons for generating these teaching resources. Their responses were also put through a word cloud to see if that would help to identify trends and common opinions or objectives. (Fig 3)

It is somewhat reassuring to see the word students figure so emphatically in this output but others which compete for attention are structure, paths, model, framing, construction, dimensionally, learning, sequence and so on.

Common teaching objectives emerging from lecturer’s comments:-

- Visualisation which helps student identification of individual building elements. (3D BIM)

- Model interaction to enable students to assemble and complete models in correct construction sequences. (4D BIM)
• Ability to in-bed information about components and elements that student could discover by interrogation of the BIM model. (4D and 5D BIM)

• Visualisation which helps students to structurally analyse buildings highlighting load paths, point loads, evenly distributed loads and aid understanding of concepts such as loaded dimensions and bracing lines. (3D BIM)

• Ability of students to work with the models in a flexible way including working remotely off campus or at home.

A curriculum review of the CS 1 module identifying topic areas to utilise BIM technologies in delivery.

The lectures and topic areas covered in this paper were analysed in detail to identify all possible opportunities where BIM models may be of benefit to teaching and thus help communicate learning objectives. The framework is quite lengthy but a sample snapshot of its’ layout and typical content is provided.

<table>
<thead>
<tr>
<th>Lecture content</th>
<th>BIM opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. District Plans and Town Planning</td>
<td>Plot densities, Planning controls, eg. Height to boundary controls, Building set backs, Rolling heights, Building size and cost per m2</td>
</tr>
<tr>
<td>4. Site Investigation 5. Surveying</td>
<td>Levels, contours, existing services, Encumbrances, Topography, Site sections, soil types, rock cut and fill requirements, excavations volumes, Need for retaining walls, Finished floor levels and height of piles above finished ground levels, Topography studies, terrain factors, sun studies, orientation</td>
</tr>
<tr>
<td>10. Concrete Slab 11. Timber Sub-floor - Breakout</td>
<td>As above with possible layering of concrete slab element build up demonstrated using BIM model, Rules regarding general saw cuts and under loadbearing walls, Using site models to illustrate when slab on ground appropriate, Cut and fill, site levels and contours to modify site for slab, Demonstration of edge details, Cut away 3D details and 2D details from model, Effect of cut outs for services, F/R/Reef models?</td>
</tr>
<tr>
<td></td>
<td>Model used to identify load paths and different types of loads, Loaded dimensions and where</td>
</tr>
</tbody>
</table>

Figure 4 - CS1 BIM opportunities snapshot (MMcGarrigle Unitec.)

Individual analysis of selected topic areas from the module to demonstrate how the BIM methods may be effectively used to help student learning.

Topic area 3 - District Plans and Town Planning.

Students referring to the North Shore district plan seeking information on Residential Planning Controls, Height in Relation to Boundary can be somewhat intimidated.
16.6.1.3 **Height in Relation to Boundary**  
a) **All residential zones except Residential 3 zone in Devonport**  

No part of any building shall exceed a height equal to 2.5 metres plus the shortest horizontal distance between that part of a building and any site boundary.

*Figure 5- Height to boundary text*  
(Source: Nth Shore District Plan. Auckland Council)

Things improve a little when the relevant diagrams are finally located in the Definitions section of the plan.

*Figure 6 - Height to boundary rules diagrams.*  
(Source: Source: Nth Shore District Plan. Auckland Council)
However a virtual model such as that shown below is far more useful as it allows a much clearer visualisation of the building, the rules and constraints which apply, the implications of any contraventions, and the possible means to resolve.

![Virtual model](image)

**Figure 7- Height to boundary model view (R Kelly Unitec 2013)**

**Topic area 6 - Timber sub-floor design Basic.**

The sections within New Zealand Standard 3604 2011 relating to the above throw up many concepts which students find challenging one of which is that of the LOADED DIMENSION defined in the text of NZS 3604 2011 as follows:

"A measure of the weight of construction contributing to the member under construction “

Far from easy for a lecturer to teach in the early stages of a course and although the standard provides diagrams they can be contradictory. Some using clear spans, others effective spans.

![Diagram of floor structure](image)

**Figure 8 - Loaded dimensions definition using clear spans (NZS 3604 2011)**

Students find things easier to comprehend when they can actually view the house frame and see where the loads originate.
Topic area 10 - Concrete slab.
Exploring this area students often have problems envisaging the elements which make up the overall construction and the actual sequence in which they are put in place. A colleague addressed these issues by employing Sketchup to develop models allowing student interaction and interrogation. Students can turn layers relating to individual elements off and on to inspect each one. “Scenes” can be saved when layers are activated showing construction sequences and made into a movie. I believe this is a simple but effective introduction to 4D BIM concepts.

Figure 9 - Model view of sub floor elements
Archicad allows quantities to be taken from the model thereby also incorporating and introducing 5D BIM concepts.
(R Kelly Unitec 2013)

Figure 10 - Sketchup concrete model showing layers tool.
(V. May Unitec 2012)

Topic area 12 – wall framing systems.
Here the ability to structurally analyse even a simple project is fundamental to the repertoire of an Architectural Technologist and useful to almost all construction disciplines. For this main reason a Unitec lecturer decided to generate a Sketchup model of a Major house project being undertaken by first year Documentation 1 students. This module is where students are expected to
demonstrate and apply the knowledge they acquired in their CS 1 module. The lecturer even colour-codes some elements to help identify load paths and highlight where specific engineering input and extra elements such as piles may be necessary.

Figure 11 - Sketchup model for structural analysis highlighting extra elements required such as piles (J Cornes Unitec 2012)

Conclusion
This research study has confirmed many issues already suspected whilst also revealing possible ideas and opportunities to help improve our tertiary sector construction education. There are already some great BIM resources generated by lecturers used effectively in module delivery. At present we do not embed BIM enough into our teaching. Many more opportunities exist to exploit the BIM products of software packages such as Archicad, Revit, Sketchup, Solibri and others to enhance student engagement and learning. If education has been able to successfully embed ILT such as Word, Excel etc into our broad teaching spectrum then possibilities certainly exist to weave BIM software into Built Environment education. Perhaps institutions in New Zealand should consider forming some sort of consortium along the lines of the UK Higher Education Academy BIM Forum to promote more the use of BIM in teaching Construction?

REFERENCES.
1. Auckland Council District Plan Operative North Shore Section 2002
4. Wordle – www.wordle.net,