Applying BIM to Sustainable Performance Evaluation in Design Projects: An Educational Approach for Architecture Programmes

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The merits and potential of Building Information Modelling (BIM) have been promoted for several years; however, its widespread adoption and development may potentially stagnate on account of a technical skills shortage, with insufficient personnel having the capabilities to successfully deliver projects. This shortfall covers all aspects of BIM, and building performance and life cycle analysis in particular. Programmes such as Ecotect, Revit, Green Building Studio, and Project Vasari, have transformed data capture and analysis, enabling architects and systems engineers to visualise site analyses and to test preliminary designs. As BIM is a relatively new process which continues to develop rapidly, Higher Education Institutions need to respond to currency and change while striving to provide graduates with the advanced skills to satisfy the needs of the building industry. This work presents a case study of the application of Autodesk's Building Performance Analysis Certificate (BPAC) as a driver for learning in support of the integration of BIM into the architectural curriculum.

Keywords: *Virtual building performance I, BIM collaboration, Data transfer, Sustainability Education*

INTRODUCTION

The merits and potential of Building Information Modelling (BIM) have been well documented in terms of productivity gains and greater efficiencies (Eastman et al. 2011). However, to fully realise the potential benefits of BIM application, the next generation of Architects, Construction Managers, and Consultant Engineers need to have the necessary technical skills and applied knowledge. BIM has been promoted in recent years as a potential solution to the successful management of Construction Project Information, but the widespread implementation and adoption of BIM has been slow, arguably due to issues such as unsatisfactory interoperability (with technological factors impeding the flow of information through the project lifecycle), cost constraints, capital investment, and skills shortages (Aranda-Mena et al, 2009). According to David Phillip (BIM Task Group [1]), BIM adoption and leadership is required to ensure that the UK is at the vanguard of

new, more efficient ways of working. Moreover, further work needs to be done on establishing the desired learning outcomes at undergraduate and postgraduate levels of Higher Education that will start to address these key issues (BIM Academic Forum [4]).

This paper reflects upon the application and effectiveness of employing Autodesk's Building Performance Analysis Certificate (BPAC) in the teaching and learning of sustainability and environmental systems at postgraduate level in Architecture. The approach adopted required students to design and develop virtual models in a 3D environment, utilising data capture, analysis, and simulation tools. These models provide visual, complex, integrated and authentic vehicles for learning, particularly for students with limited or no industry expertise. The benefits of BIM in project delivery, parametric design, and clash detection have been extensively documented and, more recently, BIM has been developed to design and procure energy-efficient and sustainable projects, responding to client demands. In this academic context, the learning and teaching strategy rejected traditional transmission modes of teaching in favour of an immersive, project-based student experience, utilising IT based data capture and applying the results to authentic design projects. Building performance software communicated and applied key components of the sustainability curriculum within the student designs, exploring their potential through an applied, authentic and meaningful approach.

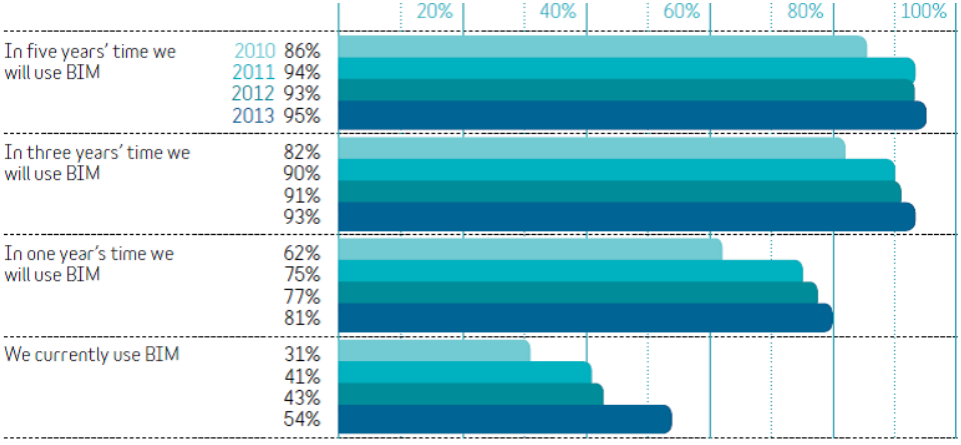
SUSTAINABILITY, DIGITAL DATA AND BIM EDUCATION

This case study critically examines the delivery of the sustainability and performance curriculum, from the perspectives of both students and teaching staff. It argues that student learning of environmental principles can be substantially improved by moving away from passive, classroom based approaches, towards the active application and visualisation of data in BIM enabled student design projects. A series of qualitative and quantitative analyses were carried out to assess the pedagogical benefits of this dynamic and virtual approach to teaching and learning. This approach sought to:

- Take advantage of a newly launched building performance online training tool to promote student learning
- Use the tool's certification system to incentivise learning and to improve student employability
- Align the taught content of the lecture series with authentic visualisation of the student design proposals
- Encourage students to apply and develop their knowledge of software interoperability in the creation of a virtual BIM environment

BIM is set to become a requirement for most public sector construction projects, with almost £1bn of public construction projects now using the technology. It is estimated that around 3% saving of project costs as a result of collaborative BIM ((Barlish & Sullivan 2012) can be achieved. Leading construction and supply chain companies have been embracing BIM processes and principles for several years. Countries such as the UK, Canada, Australia, China and Norway have set a range of self-directed targets for the adoption of BIM in the procurement of major public sector projects in the next few years (BIM Task Group [1]). A survey in the UK by the NBS (National Building Specification) by nearly 1,000 construction professionals representing a range of business sizes and disciplines from across the industry including architecture, engineering and surveying. revealed that companies cite costs as a major barrier to wider adoption of these systems. It was however also reported that a lack of technological skills, BIM-enabled employees, and resistance to practice change were also viewed as key constraints (Fig. 1) indicates that year on year the acceptance of BIM is increasing understating and acceptance of BIM. It is also striking that looking at the data that the adoption rate now is more than that project by those who were aware of BIM in 2010.

Figure 1
Projected use of BIM among those aware of it



CURRENT INITIATIVES TO PROMOTE BIM ADOPTION

The recognition of skills shortages in the construction industry workforce has led to multiple approaches, policies, and initiatives to increase BIM adoption. Professional bodies have created BIM academic forums, in response to policy drivers, leading to initiatives at a variety of levels:

International

Collaborative ventures, such as BIM live events, have sought to demonstrate the international potential of BIM technologies. In particular, international design competitions have been held to design and construct projects in the United Kingdom, Singapore, Australia and Qatar (BIM Academy [2]). Entries have been submitted by collaborative teams of consultants and students from multiple countries.

National

The UK BIM task group [1] has been tasked with the development of standards such as PAS1192 , which has been promoted as the UK specification for Building Information Management exchanges. Professional bodies, such as the Royal Institute of Chartered Surveyors (RICS), have also commenced the delivery of specialist distance learning programmes. The BIM Academic Forum has concurrently been developing the BIM Academic Framework, with a view towards a long-term vision of incorporating BIM learning at appropriate levels within 'discipline-specific' undergraduate and postgraduate courses, thereby facilitating the development of relevantly-skilled professionals capable of delivering BIM driven construction projects.

Regional

The creation of 11 regional BIM hubs in autumn 2012 sought to raise awareness of the principles and benefits of the new programmes, thereby promoting the early and widespread adoption of BIM processes and working methods throughout the UK's construction industry

PROFESSIONAL ORGANISATIONS AND THE INTEGRATION OF BIM

From a UK perspective, a number of key professional bodies represent the key stakeholders within the British construction industry. These include the Chartered Institute of Building (CIOB), the Chartered Institute of Building Services Engineers (CIBSE), and the Chartered Institute of Architectural Technologists (CIAT) and as well as the Royal Institute of British Architects (RIBA) and the Royal Institution of Chartered

Surveyors (RICS). Each professional body contributed their view of the future of the process to the BIM Academic Forum. This exercise highlighted a range of methods of adoption and education, including Distance Learning (DL) modules and an over-arching BIM competence exam. It was also recognised from this exercise that extensive BIM education could give rise to a reduced workforce in light of improved efficiencies to the construction process. Another key aspect of the conversation is the relationship of BIM to Higher Education, and whether the attributes required of construction personnel can be satisfied by technical skills training, or can only be satisfied by higher levels of intellectual and critical engagement. This aspect of the wider conversation is, to some degree, addressed within this paper.

INTEGRATION OF BPAC INTO TEACHING BIM

The overall benefits of BIM in sustainable design have been researched extensively in recent years. Krygiel & Nies (2008) suggest that BIM can be used to develop sound environmental design strategies with respect to the following areas; the choice of building orientation, whereby selecting efficient sites and aspects can reduce energy costs; the development of building massing - to analyse the proposed built form in order to optimize the building envelope; and daylighting analysis which can be used to reduce the need for artificial lighting, reduce the potential for glare and overheating, and/or capitalise on passive heating strategies . To some degree, teaching the authentic and accurate application of such topics to young designers and engineers (as opposed to teaching the principles) has been challenging, due to a requirement for advanced skills in software, data capture, and data analysis. However, the recently developed Building Performance Analysis Certificate programme (BPAC) provides an educational method for architecture and engineering students who wish to conduct authentic performance analyses in the creation of highly sustainable and/or energy efficient buildings. This online programme was launched in 2013, having been developed by worldwide experts in sustainable building physics. The programme's intention is to enable construction design students to improve their fluency in the strategies and tools of sustainable building design. The course comprises seven modules in climate analysis, sun path studies, building massing and orientation, solar radiation analysis, wind analysis, and other aspects related to building environmental performance. The content of the programme includes:

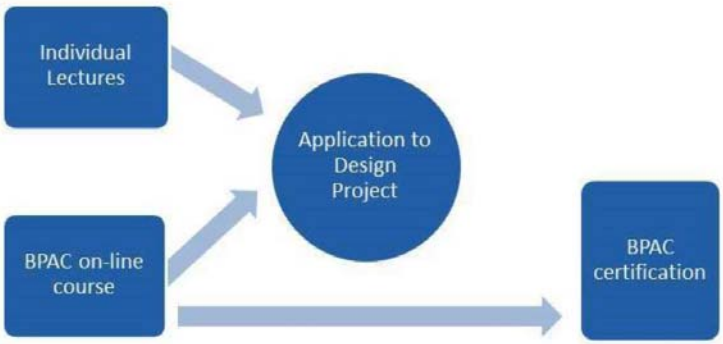
- A clear "introduction to software" section within each of the seven modules
- Small clusters of content and quizzes that students can complete in short amounts at a time
- Case-based examples and questions
- Content focused on energy fundamentals and modelling with detailed Revit models
- Application of Revit-based tools (including Revit, Vasari and Green Building Studio)

The Autodesk Building Performance Analysis Certificate is currently being piloted by students and educators around the world, and Northumbria University has elected to incorporate the new offer within its architectural design curricula. The programme intends to bridge the gap between fundamental concepts of environmental design and valuable software practices to encourage accurate and meaningful analyses for building optimization. Further, advanced programmes for professionals are currently in development (Autodesk 2013).

METHOD

The approach adopted was to incorporate a discrete element of BIM design within a postgraduate course of architecture, in a relatively low-stakes fashion for students who had a variety of experiences with BIM, ranging from zero to one or two years of competency. On completion of the exercise, the intention

Figure 2
Constructive Alignment of Teaching and Certification



was to evaluate the learning in terms of the student experience and engagement, as well as the quality of the application to student design projects. This was undertaken with a view to informing future direction and educational strategies towards wider disciplinary BIM adoption within the Faculty of Engineering and Environment. Self-directed learning was encouraged, given the masters level curriculum of this award, and certification after the successful completion of the BPAC programme provided an additional incentive with respect to esteem and employability. It is a consideration that this individual module could form a stepping stone towards programme wide implementation of BIM technologies across the Construction and Architectural related programmes within the faculty. Figure 2 describes this proposed dual benefit of the taught and certified approach which could perhaps be similarly applied to packages such as Revit, Green Buildings Studio (GBS) and Project Vasari.

To some degree, it can be argued that the use of a central architectural design project in this project-based curriculum model echoes the assertions of Biggs and Tan that active learning is predicated on the basis of relevance and need (Biggs & Tang, 2011). As espoused by the same authors, it can also be considered that the teaching, assessment and outcomes of the module are constructively aligned within the module itself, as well as aligned to the development and iteration of the central design project. As part of the module evaluation process, participants were asked a series of questions regarding their experiences, including consideration of how the overall programme could be developed and improved. An anonymous online questionnaire was designed, utilising a five point Likert scale (from strong agreement to strong disagreement). The cohorts' qualitative views were also complied for thematic analysis.

Preliminary Results

This section analyses the outcomes of the module evaluation with respect to student opinions of both the BPAC online tool, and the associated certification of their applied learning and skills. As part of the survey, comments were invited on student perceptions regarding the future roles of BIM and Building Performance Modelling.

Quantitative Analysis

The results demonstrate strong correlations in terms of the cohort's expectations of BIM's importance in benefiting their future professional and career developments. With respect to building performance analysis, there was overwhelming agreement that this is a critical element of architectural design that needs to be addressed more comprehensively at curriculum

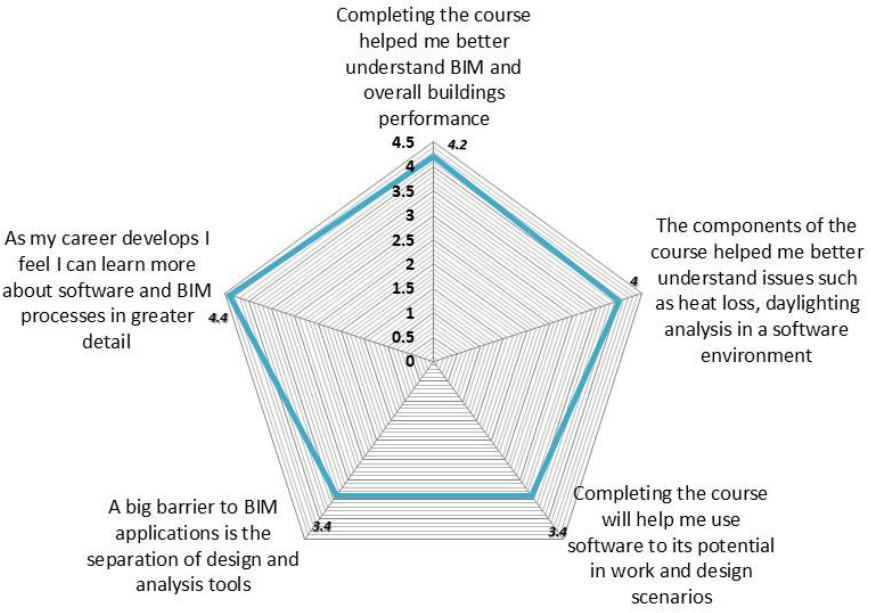


Figure 3
Diagram of Quantitative Responses

level. In addition, the format of the module greatly helped in the delivery of 'dry' topics such as heat loss, orientation, and daylight factors, which are often perceived as dull subjects, and difficult to teach in isolation from the application of this knowledge. The quantitative results assert that the overall benefits of this method are significant, in communicating such topics through active learning and application of this knowledge.

Qualitative Analysis

A number of key themes emerged from the student responses to the module evaluation. Primarily, a low-stakes opportunity to engage with the new technologies was appreciated, with the module being perceived as a '... good way to start understanding BIM and its uses"; "It was a strong introduction to a very broad topic, it covers the basics very well".

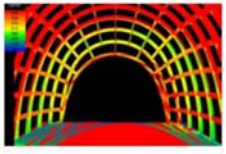
The certification aspect of the BPAC offer was also applauded; "completion of the course provides a good addition to your C.V. which will be valuable to employers who require employees with BIM knowledge".

In terms of practical learning, the alignment to the central design project was seen as essential to student engagement with some of the subject matter; "I think a more interactive approach might make for increased engagement with the subject matter. It did become very dry in several places".

However, a note of caution was sounded regarding the potentially prescriptive application of the new technologies; "It feels like BIM may restrict architectural design...however, if it means being able to use BIM will make architecture students more employable, then it is something that should be encouraged in architectural education"

The qualitative feedback also address important issues in terms of environmental issues being foundational to the design process, and central to the successful development of design concepts. The impact of this initiative was far reaching, allowing the cohort to apply the principles learned to the design

project at a formative stage. The multi-media and applied nature of the BPAC programme appeared to be highly effective, particularly for these Masters level students of Architecture, who employ visual methods extensively. Their design proposals were enriched by a visual facility to demonstrate the effects of time and orientation on buildings, allowing testing and modification of the design proposals at the feasibility or concept design stages. This virtual modelling technique offers richness and relevance in lieu of 'chalk and talk' didactic transmission. Figure 4 illustrates how a student design proposal can be used to accurately model daylighting within a key space. This is contrasted here with the mathematical equation method which can bear no relation or relevance to the learner in its abstract and reductionist language:



$$DF_{AV} = \frac{T.W.\theta.M}{A.\left(1-R^2\right)}$$

Figure 4
BPAC visual modelling of design proposal; standard daylight factor equation (courtesy of Fabien Danker Masters Student Vasari simulation of for environmental site analysis)

Similarly, the BPAC software enabled the architecture students to model and apply external weather conditions typical of the project's site and locale, including the representation of direct solar radiation representation by incorporating BIM enabled visualisation methods from the use of Project Vasari (Fig. 5).

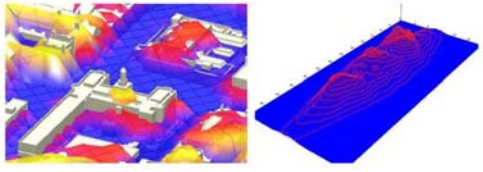


Figure 5
Project Vasari environmental modelling outputs applied to design project (courtesy of Fabien Danker Masters Student Vasari simulation of for environmental site analysis)

BIM WIDE ACTIVITY AT A FACULTY LEVEL

Proposals have been tabled for an inter-disciplinary project that incorporates teaching and students from across the Faculty of Engineering and Environment, with the aspiration of mirroring and encouraging the collaborative working processes required for large scale BIM projects. This is likely to provide a variety of challenges for both staff and students; for architecture students, this may counter the tacit notion of the 'lone genius' as promoted in disciplinary and popular media. This has been addressed by initiatives in pedagogy, such as the use of inter-disciplinary Virtual Construction Models (VCMs) at the University of Technology Sydney; this project utilises a central design project at the heart of teaching and learning approaches to planning, construction, and operation (Forsythe et al 2013). The rich data content of such intelligent models enables a move forward from high quality visualisation software towards the critical use of embedded parametric information, which can contribute to more effective design and delivery of the project's overall environmental building performance over its working lifecycle.

CONCLUDING REMARKS

The findings contribute towards identifying effective methods of incorporating BIM into the postgraduate education of architectural students. Critically, the use of BPAC, and its active and contextual application to studio design projects appears to provide a powerful learning strategy for the application of building science principles, as well as a manageable introduction to the potential of BIM. This is the beginning of a journey for BIM based sustainability education at Northumbria University, which is one first UK Universities to adopt this Autodesk backed initiative. Future developments may include applying the lessons learned towards a wider curriculum that exploits 3D, 4D and 5D design project environments, as well as strategic approaches to collaborative, inter-disciplinary working. In addition it provides greater development of student- student and educator interactions.

It must be re-stated that the effective implementation of BIM requires as much consideration of people as it does of the technical processes. The teaching and learning environment should therefore seek to address the three components of people, processes and technology (Forsythe et al 2013). Without appro-

priately and strategically considering these elements in a holistic fashion, the current fragmentation in the adoption of adoption of BIM might not substantially change. The inclusion of BPAC training within the curriculum at Northumbria therefore required 'buy in' from staff and students of the key aim was of introducing graduates to BIM experts, through a method which respected their capacity for high level architectural design. These interim results indicate that the students clearly see value in this approach. While individual students had varying knowledge and experience of software applications, the results indicated that the independent learning method of BPAC allowed them to complete the course with little need for didactic transmission of content. These students, having completed at least one year out in industry, were eager to learn BIM, particularly Revit, which is used extensively in architectural practice. The opportunity afforded by BPAC to engage more deeply with sustainable design provided an additional and relevant expertise to their professional experience.

REFERENCES

Aranda-Mena, G., Crawford, J, Chevez, A and Froese, T 2009, 'Building information modelling demystified: does it make business sense to adopt BIM?', *International Journal of Managing Projects in Business*, 2(3), pp. 419-434

Barlish, K and Sullivan, K 2012, 'How to measure the benefits of BIM — A case study approach', *Automation in Construction*, 24, pp. 149-159

Biggs, JB and Tang, CS 2011, *Teaching for quality learning at university -4th ed*, Open University Press, Maidenhead

Forysthe, P, Jupp, J and Sawhney, A 2013, 'Building Information Modelling in Tertiary Construction Project Management Education: A Programme- wide Implementation Strategy', *Journal for Education in the Built Environment*, 8(1), pp. 16-34

Krygiel, E and Nies, B 2008, *Green BIM: successful sustainable design with building information modelling*, Sybex

[1] BIM Task Group (2014), available at http://www.bimtaskgroup.org/

[2] BIM Academy (2013) Build Sydney live, available at http://collab.northumbria.ac.uk/bim2/build-sydney-live-team-bim-academy

[3] National BIM Report (2014), available at http://www.thenbs.com/topics/bim/articles/nbsNationalBimSurvey_2013.asp

[4] BIM Academic Forum, availailable at www.bimtaskgroup.org/bim-academic-forum-uk/