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## INTEGRATION OF BIM IN HIGHER EDUCATION: CASE STUDY OF THE ADOPTION OF BIM INTO COVENTRY UNIVERSITY'S DEPARTMENT OF CIVIL ENGINEERING, ARCHITECTURE AND BUILDING

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**Abstract.** *In the context of Architecture, Building Information Modelling (BIM) is a design methodology which enables all of the design details, decisions and characteristics to be held within a collaborative digital representation and information package. The design and project information can then be shared, accessed and altered live, facilitating an efficient and fluid collaborative design and asset management process across the whole life cycle of a building. It is argued that BIM has many benefits for projects such as reducing waste, improving the efficiency and enhancing collaboration between different parties to a project which can lead to improved quality and also cost and time reductions. Government drive indicates that BIM skills and information sharing, protocols and processes are essential for improving efficiency of design and operational performance of buildings. It is therefore important that the principle of BIM is integrated into the training of future construction professionals. The aim of this paper is to outline the process that has been undertaken to integrate BIM within the undergraduate curriculum at Coventry University's Civil Engineering, Architecture and Building (CAB) department. A critical analysis of a case study construction engineering department has been carried out to inform the development of the strategy for integration of BIM within existing course structure. The case study offers a lesson on the adoption of BIM to enhance the student skills and understanding relevant to their professional disciplines.*

**Keyword:** *Building Information Modelling (BIM), collaboration, higher education, low impact buildings, sustainability, integrated design*

## 1 INTRODUCTION

The Department of Civil Engineering, Architecture and Building (CAB) at Coventry University recently embarked on the task of integrating BIM theory and practices across its undergraduate and postgraduate degree courses. The department has a clear objective that it wants all students on graduation to leave, with a greater awareness of 'BIM' and the practices involved through both theoretical and practical skills. Smith et al (2009 p.xxvii) argues that “Building information modelling is nothing more and nothing less than a systems approach to the design, construction, ownership, management, operation, maintenance, use, and demolition or reuse of buildings. A building information model is any compilation of reliable data in single or multiple electronic data formats, however complete or incomplete that supports a systems approach in any stage in the lifecycle of a building”. This may be seen by some as an over simplification but in essence if all members of a project team collaborate together, through the entire project life cycle with BIM theory at the core of the design process the benefits that can be achieved are vast.

A core feature of working within a BIM environment is the drive towards encouraging multi-disciplinary collaboration from the very outset of a project. The benefits of all disciplines working together within one core BIM environment are multiple. A major issue that is experienced within non BIM design processes is the matter of conflict in different design outputs. The ethos of having a core central BIM model is to facilitate a smooth transition through these issues by identifying conflicts earlier on in the design and construction process thus reducing the negative effects on time and costs. Projects can be visualised and evaluated early in the design process allowing the client and designer alike to optimise the design with regards to special and environmental performance.

Angela Brady (2012) states in the RIBA BIM overlay plan of work, "the aim (of the BIM overlay) is to assist design and construction teams in using BIM to provide a more efficient, intelligent and cost effective design process and to offer enhanced services to clients, particularly in relation to the whole life of buildings".

## 2 METHODOLOGY

The research has been carried out using critical evaluation of content of undergraduate courses within CAB department in Coventry University as a case study for integration of BIM into Higher education. The research also relied on the critical review of current knowledge in the areas of government policy, application of BIM in the construction industry and the integration of BIM into higher education courses. The evaluation uses a descriptive case study approach where a critical evaluation has been carried out of the current state of courses relative to the opportunities for collaborative working practices with a view to integrate BIM throughout the undergraduate degree and improve the ability of students to develop critical skills required in the construction sector. Coventry University has been using Project Based Learning (PBL) to provide an opportunity for students to work in groups and therefore have the opportunity to practice aspects of collaborative working practices expected in the construction industry. The case study approach used in this paper also looked at this collaborative working platform and reviewed its effectiveness relative to the application of BIM through the PBL. Stage 1 of the study will evaluate department's current initiatives to integrate BIM into the various aspects the courses. Stage 2 of the study will evaluate the departments' future development plans to further implement the BIM integration strategy.

### 3 DRIVERS FOR BIM IN HIGHER EDUCATION

Over the last few years the UK Government has made significant moves outlining where they expect the construction industry to be over the coming years in regards to BIM. The UK Government has mandated that all public building projects will have to be using BIM design processes at level 2, fully collaborative 3D BIM, or higher by 2016. As Francis Maude (2012), Minister for the Cabinet Office states, “The Governments four year strategy for BIM implementation will change the dynamics and behaviours of the construction supply chain, unlocking new, more efficient and collaborative ways of working. This whole sector adoption of BIM will put us at the vanguard of a new digital construction era and position the UK to become the world leaders in BIM”. The Cabinet Office states in the Government Construction Strategy (2011) “there is a detailed programme of measures Government will take that will reduce costs by up to 20% by the end of this parliament”; it is believed that BIM will be one of the key factors in achieving this target.

As discussed in the BIS BIM strategy Report carried out by the BIM Industry Working Group (2011, p6) “key to any successful change programme is communication of the change and adequate support during the process”, part of the responsibility to provide that support will fall on Academic Institutions. The BIS BIM strategy Report (2011, p6) goes on to state that in regards to how training is provided the “recommended solution is a strongly led hybrid provider drawing on the educational and research expertise of universities, the robust experience of accrediting bodies and the engagement of credible industry led best practice, as well as vocational training delivered by CPD or the training supply chain.”.

Barison and Santos (2009) found the application of BIM in HE to be focussed predominantly on single course integration rather inter-disciplinary. However, the application of BIM in the industry is an integrated practice that allows for effective collaboration between different professionals. It is with these facts in mind the CAB Department has started to incorporate BIM across its degree programmes, with the aim of improving the BIM awareness and skills necessary for which will be necessary for effective cross or inter-disciplinary collaboration. Another key driver in the push for wider adoption of BIM across the industry is the positive effects that BIM working practices will have in regards to delivering low impact sustainable buildings for the future, in an increasingly energy conscious time. The target is that by increasing the BIM awareness and skills of students, whilst at the same time parallel to these increasing students’ abilities to analyse and design low impact buildings, graduates will be in the best placed position to contribute positively to the future of the construction sector.

The National BIM Report 2012 canvassed the opinions of over 1000 participants with differing levels of awareness and understanding of BIM for 2011. The results show that 73% of participants agree that the industry is simply not yet clear enough on what BIM actually is. Following on from this, NBS repeated the survey in 2012-13 titled the NBS National BIM Survey 2013, canvassing the opinions of the industry for the year 2012. The same question was asked and this time around 74% now felt that ‘the industry isn’t yet clear enough on what BIM is yet, clearly there is still further work to be done in regards to preparing the industry. Also highlighted within the findings is the lack of awareness amongst all participants. The National BIM Report 2012 established, “that awareness of BIM is (was) not universal, with 21% of participants stating that they were not aware of BIM (in 2011)”. In the repeated study, NBS National BIM Survey 2013 the same question was asked again, this time around however the number of participants ‘neither aware nor using BIM’ fell to 6%. This result is a marked improvement on previous years amongst the industry participants. As good as an

improvement as this last result is it would be somewhat counterproductive if Higher Education institutions allowed graduates to leave university without any awareness of BIM themselves. This could hinder the Government and industry in their push for greater adoption of BIM, whilst at the same time hindering graduates chances of gaining the opportunities they strive for. It is one of the responsibilities of Higher Education institutes to provide graduates with the necessary skills to succeed with an increasingly competitive industry, with an awareness and ability to work within a BIM working environment being one of those skills.

The extent to which BIM is adopted across the construction industry depends on whether industry leaders buy into the Governments sentiments. Currently major players within the industry are making strong drives towards the adoption of BIM, with some already delivering projects at maturity level 2. Balfour Beatty has recently invested a considerable amount of funds into the adoption of BIM across their company. In 2012 Balfour Beatty “signed a three year, \$12 million agreement that will help Balfour Beatty expand its adoption of Building Information Modelling (BIM)” balfourbeatty (2012). Capita Symonds have also been investing heavily in the adoption of BIM they announced that from “July 2012 all its new design projects will use BIM Level 2 as standard” capitasymonds. (2013). The Royal BAM Group also recently signed a three year contract worth “(£2.8m) with software firm Autodesk to provide Building Information Modelling (BIM) technology across its global operations, including all BAM projects in the UK” building (2013). Speaking about the deal in October 2012, BAM Construct Design & Marketing director Chris Gilmour stated that BIM would be used across all projects, “Not just special projects – no matter how big or small the project, we will be fully embedding BIM” www.building.co.uk (February 2013). This review of the construction industry is by no means exhaustive; it is however a small indication of the commitment that industry is making towards adopting BIM.

## **4 STRATEGY FOR INTEGRATION OF BIM IN THE CAB DEPARTMENT**

### **4.1 Stage 1 – Current Initiative**

The first stage in enhancing students awareness of BIM was taken through the introduction of a 'Project Implementation Plan (PIP) coursework' (which can otherwise be known as a BIM execution plan) for a second year inter-disciplinary group project involving 230 students working in groups. This particular idea concentrates on the 'Information' aspect of BIM. There is no design aspect to the projects, just a clear focus on the PIP document to effectively plan the projects, emphasising collaborative and integrated working practices. The next step is to improve students awareness of BIM through lectures on theory and context. This is driven by the findings of NBS National BIM Survey (2012), which finds 74% of participants agreed that the industry was simply not yet clear enough on what BIM actually is. The expectation is that these BIM awareness lectures will help to address this issue.

### **4.2 Stage 2 - The Future Initiatives**

The second stage aims to further incorporate BIM across the undergraduate courses. The aim is to give first year students a taste of the collaboration skills required for group work at the very start of their studies at Coventry, without explicit reference to 'BIM'. The early exposure of students of the principles of BIM will ultimately smooth the learning curve as they encounter these issues through their course. In addition technical tutorial support will be provided to second year students from all construction and engineering courses through BIM

software workshops.

In addition, the department is reorganising its third year multi-disciplinary collaborative integrated project module with the aim of getting the best BIM integration as possible. The final year project runs with around 250 students, working in groups from multidisciplinary backgrounds within the CAB Department. The ethos of the module is to replicate collaborative construction industry processes, as reasonably close as possible, within an academic setting. The module aims to develop knowledge and skills that will help the student's capacity for group integration, across various construction professions, by undertaking a major construction scenario-based project. Students are expected to synthesize the knowledge gained in taught modules and apply these skills and abilities to the development of a project from inception through to tender. Of equal importance to these technical skills is the personal and professional skills that the students are expected to further develop through participation in the Integrated Project. These include the development of critical, analytical and transferable study skills, which are of practical benefit in the workplace and key to continued professional development. The module has been running for a number of years and therefore the infrastructure that is currently in place for this module opens up a valuable opportunity to integrate live BIM practices. The aim is to realign the module to suit the departments BIM learning requirements.

The first steps that have been embarked on are to establish exactly what level of BIM competency the students need to achieve. Establishing the level of BIM that is feasible to integrate within undergraduate students is an ongoing point of discussion that will need to be continually evaluated and developed. The expectation is to improve the student awareness in the practices and processes involved in working on a BIM collaborative and integrated project. The module team is building on this platform and in essence is repackaging the module with a greater emphasis placed on the BIM collaborative processes and the sustainability of the project. For the wider range of parties involved in the project the concentration may be more on the 'Information' sharing aspects of BIM. Working within a BIM environment, adopting BIM information sharing protocols, collating the data in an interoperable format, and utilising documents such as the 'Project Implementation Plan' aims to improve how information is shared amongst all the varying parties involved.

There are two major aspects to the project, the first will be the low carbon refurbishment and redevelopment of the case study building and secondly to design new extension directly attached to the case study building. The refurbishment task requires initial benchmarking of the current building performance against similar buildings in the sector. Effective collaborative effort between teams will have to be demonstrated in the proposed improvement strategy with respect to functionality and energy performance criteria. The team will be required to predict the effectiveness of design choices and going through reiterative process to optimise the design. The second part of the project will be to create a new modern extension to the case study building. The teams will be required to create an optimised architectural design and focal point.

The overriding core directive for the project will be the BIM coordination and collaboration. Teams will be directed to ensure that they adhere to a BIM ethos and collate the team's project information into an interoperable design package. Running under this core directive will be three key main threads; the architectural design, the structural design and the sustainability strategy. The aim will be for the three key main threads to integrate seamlessly with each other. Sustainability has existed in previous entities of the module so is not

something completely new, however, a greater emphasis will now be placed on this area ensuring that the project replicates the industry's desire and need for low impact design and sustainable buildings for the future, allowing students to graduate with a greater understanding of BIM working practices and low impact design strategies.

To immediately immerse the teams into a BIM working environment, the teams, once formed, will be presented with the task of formalising the groups 'Project Implementation Plan (PIP)'. The PIP plan will set out the working and information sharing protocols for the teams from the outset. The PIP plan will be a follow on from the PIP plan all students completed in year 2. The idea is that by having completed a smaller PIP plan, the learning curve progressing on to the year 3 PIP will be reduced. The result being that when students embark on the final year Integrated Project they will already be familiar with the PIP plan and therefore BIM working and information sharing processes and protocols, enabling them to adopt a greater understanding and emersion of BIM within the final year Integrated Project. The emphasis at this initial stage will be for students to firm up their information sharing protocols to ensure that the full team is aware of the agreed processes and directives.

A predominant element of the new Integrated Project format will be the designation of a BIM coordinator role as well as the creation of a BIM coordination task (BIMC). It will be the job of the BIM coordinator to ensure that the BIM content and coordination is developed and maintained, to ensure that all the team members collate and present all information in one cohesive document, printed and electronic. The separate task will set out directives to assist the BIM coordinator in understanding their role. By creating a separate task and a titled team member's role the aim is for the BIM coordinator to lighten the workload of all the other members in regards to information processing and exchange, crucially reducing the workload of the lead designer who in our case will be acting as the model manager in the later stages of the project.

As well as the BIMC task, each group will be provided with a base 3D model of an existing university building. The base model that the students will receive as a 'starting block' will be provided in two different formats, REVIT and SketchUp. Students who progress through the different degree courses will gain a differing set of software skills depending on the requirements of each specific course, hence the variation in the format of the base model provided. This therefore represents a micro representation of one of the main issues that the industry is facing in regards to a lack of the required skills amongst staff. Therefore, Coventry will be adopting an 'OpenBIM' approach to the module, where all groups will have to ensure that file sharing and interoperability are carefully considered.

Groups will need to produce plans of their design and amend the existing 3D model; the software adopted will depend largely on the previous experience of the team members. The groups will then be tasked with creating a new extension to the existing building in response to the scenario brief requirements whilst also considering and developing ideas on how they can upgrade the existing structure on site. The idea of using both of these approaches, existing building interrogation and new build extension is significant. Industry consultation has shown that through using an existing building, which would be surveyed, evaluated and then upgraded to improve the energy performance, the students experience a potentially valuable side of BIM, 'BIM used as a tool for the energy improvement of existing buildings'. At the same time having each team design an extension to the existing building opens up the door for groups to be able to gain skills in areas of new design processes. The aim is that by having

these two different approaches to the scenario brief students will be able to access the most rounded BIM experience.

Each group will have to consider how they can upgrade the existing building with the aim of improving the energy performance. The sustainability strategy will be an extremely important aspect which teams will have to consider carefully, a minimum BREEAM rating of 'very good' will be requested for the existing structure with a rating of 'excellent' for the new extension. Existing building stock presents an important area of opportunity and challenge for reducing carbon emission in Europe. It is believed that BIM information processes and modelling will be an important tool in the future, utilised to analyse and upgrade existing buildings, improving the facilities management and energy performance of current building stock. The task will be set up to involve multi-disciplines in the process of energy survey and low carbon redesign. This project will focus on an energy survey of the existing building and benchmarking that against similar types of buildings within the sectors, this energy survey will allow the students to identify areas of improvement. The students will be expected to develop a strategy for low carbon refurbishment and predict the benefits of such interventions using thermal modelling software. The collaboration in this instance will be achieved through understanding of inter-operability of different software environments such as sharing files between 2D CAD, BIM software (3D modelling and BIM platforms), and thermal modelling software such as IES Virtual Environment and Ecotect. It is expected that this aspect of the work will lean heavily on all professional disciplines. The target is that by ensuring that all team members are involved in the sustainability strategy all of the team will need to be aware of the consequences that their decisions have on the environmental impact of a design. The integration of the sustainability strategy findings with the architectural/structural design will be closely reviewed with the aim of creating a distinct sustainable strategy which needs to be seamlessly integrated with the design teams processes and therefore increase the low impact design awareness of all graduates.

The Civil Engineering teams of each group will be tasked with creating a structure for the new extension; students will be given free rein to design the initial structure on any CAD design platform. The next key step will be to get each Civil Engineering team to then transfer this data into a 3D BIM platform, if they haven't already used one in the first place. This is one of many processes in which interoperability of students working environment is crucial. To successfully complete the task students will have to demonstrate an understanding of the interoperability of software. To assist in this crucial step of the design process all groups will be offered support and tutorials to assist them, likewise to other processes that may be unfamiliar to students. The major benefit in having a 3D model of the structure will be that it can be analysed and interrogated within the BIM and structural analysis software. Each Civil Engineering team will be allocated certain tasks requiring them to integrate their structural designs further, giving them a greater understanding of the capabilities and benefits of using 3D parametric software. The ability for Civil engineers to be able to demonstrate an understanding of how to interrogate 3D structural design software aims to lead to improvements in the programming, cost and the integrity of structural designs.

Throughout the integrated project there will be a number of aspects to ensure that groups develop and demonstrate an understanding of interoperability. Teams will be tasked to merge their differing models (structural design model and Architectural design model). At this point groups will receive learning on how to model share regardless of format. During the model merging process teams will have to utilise IFC data standard import and exports. The aim of

the task is to ensure that students become aware of the interoperability of data sharing and the demands and consequences that it has on the design process. Each model will be evaluated, manipulated and analysed as the group's progress through the module. As previously discussed teams will continue to investigate the effectiveness of design choices adopting a reiterative design process. The target is to move individual team members away from 'silo'd' design processes towards collaborative and integrated working practices. The aim is that through replicating some of the challenges which industry will need to overcome to achieve BIM maturity level 2 and level 3 and by moving away from isolated design practices, graduates will develop the skills required to successfully work within a BIM collaborative and integrated working environment.

The teaching processes of BIM will be supported by a range of 3D BIM models. The emphasis for first year students learning is on domestic buildings, as such a BIM domestic house design is being created. The model will be completed to such a level that it can be interrogated, analysed and navigated, including multiple points of interest such as MEP detailing, cost/quantity take-offs and energy analysis. Although in reality a BIM model may not be required for a domestic design, the ethos is that if students are made aware of the processes involved in creating, interrogating, analysing and navigating a BIM model within a simplified context then it should reduce the learning curve on more complex models. The emphasis for second and third year students is larger buildings. Two university estate buildings will be modelled and completed to an intensive level enabling a multitude of interrogation and analysis to be carried out by students and staff for training purposes. The two buildings will be the recently opened Engineering and Computing building (ECB) and the student's main place of work within CAB the Sir John Laing Building. The Sir John Laing (JL) case study will provide the opportunity for CAB students to evaluate and analyse the building that they use everyday. The intention is that by using a familiar building the engagement of the students will be stronger. The buildings can then be taken through multiple BIM design processes enabling them to be interrogated, analysed and navigated by staff and students alike. The objectives of creating these 3D BIM model teaching aids are numerous. In one instance the models can be used by teaching staff across numerous programmes allowing lecturers the ability to visualise different concepts to different students. Another use of the models will be to allow students to actively engage within lectures and tutorials by utilising the BIM models. The intention is that the models will not solely be used for teaching BIM. The aim is for staff to utilise the models across multiple disciplines and modules, whether it is a first year construction technology module, showing details of a house design, or a second year lecture on 'BIM Awareness'. Further to this the models can be used as a teaching aid for building service engineers showing service installation details. Therefore, the aim is for the models to become an integral part of teaching within multiple modules.

## **5 A CRITICAL ANALYSIS OF THE CURRENT AND FUTURE INITIATIVES**

The target to provide all students with an awareness of BIM practices, regardless of discipline, is in response to the lack of skills and knowledge across the industry that currently exists in regards to BIM. As stated in the BIS-BIM-strategy-Report (2011, p6) which was carried out by the BIM Industry Working Group, by "engaging providers in the development and delivery of the material and standards will not only accelerate competency and adoption, but also will align the level and calibration of future industry professionals emerging from universities and provide a structure for lifelong development learning around BIM". The

expectation is that Coventry will be providing the industry with graduates that are capable of working efficiently as part of a BIM project. It is questioned that currently as things stand within the construction industry a severe lack of skills and knowledge exist which needs to be addressed. It is this within this area that Higher Education has not only the facilities and ability to assist the industry but also the responsibility to provide graduates and the industry alike with skills which are transferable and applicable to what the industry requires today and in the future in regards to BIM and all other industry practices.

## **6 CRITICAL REVIEW OF THE CHALLENGES**

A framework developed by Hopkins (2006) on the 'Challenges and Barriers to Education for Sustainable development (ESD)' has been used to review the challenges and barriers that Coventry University may face in the process of integrating principles of BIM into all aspects of course and modules delivery. Even though the framework developed by Hopkins was focusing on the challenges faced by ESD, many of the issues identified are applicable to the challenges that will be faced in the adoption of BIM in education. One of the first challenges is to increase the awareness of BIM amongst the existing teaching staff within the Department. If BIM is to be developed across all undergraduate courses then staff that may not be directly impacted by BIM still need to be made aware of it and why the Department is pushing forward in this direction. Additionally, more specialised individual professional learning will be required by staff to ensure that all those involved in the delivery of BIM are competent. However, individual professional development is something that is welcomed amongst all those involved. The next issue concerns the integration of BIM across the CAB curriculum. It has been decided early on that all students should gain an awareness of BIM. The difficulty with this is ensuring that the differing disciplines gain the appropriate amount of awareness and skills needed, beyond that of the initial 'BIM awareness lectures'. This is something that will be continually developed and assessed as the research continues. Another issue is dealing with the complexity of BIM concepts. It is paramount that the skills and theory that are to be taught do not confuse students more than when they started. As Charles Hopkins (2006) stated within his work, when something is hard to define it can also be difficult to teach, an aspect that BIM is guilty of. Another challenge to be considered later on will be changes to the current courses, in regards to BIM. The courses within the department are set up carefully to cover many specific learning outcomes needed within the professional context. The challenge will be for the Department to integrate BIM seamlessly within the structure of existing courses and modules. Therefore, an important criterion concerning the success of the adoption of BIM will be the sharing of the responsibilities. The team feels that the adoption of BIM into an education setting cannot solely be the work of one BIM initiator. The correct framework needs to be in place amongst all staff. Departmental heads have provided support regarding the adoption of BIM, which each member of the team is aware of. This has ensured that everyone involved is pushing in the same direction.

## **7 CONCLUSIONS**

BIM is a crucial part ensuring a reduction in time, cost, waste and carbon consumption. The skills gap in the industry can only be closed through integration of the principles of BIM throughout the fabric of undergraduate courses in HE. The CAB department is making good steps towards the adoption of BIM across the undergraduate degree courses at Coventry University. This case study reflects both the current stages and future plans for the integration

of BIM in the department including critical evaluation of possible challenges and opportunities. Over the next few year's valuable data and insight will be gathered by the Department to assess the effectiveness of the steps taken. The Department will continue to develop new ways of engaging students and improving their soft and hard skills, relevant to successful practice in a multi-disciplinary field of construction. The aim is to teach more efficient design processes which lead to reduced time, cost, waste and carbon consumption whilst also enhancing skills of building design and information sharing processes leading to greater integration and collaboration. The interrogation of designs will also be a large aspect of the student's studies, with improving the sustainability and efficiency of building a key theme. The next steps for the Department will be to continue to develop new BIM integration strategies whilst at the same time continually assessing the effects of the current strategies that have been implemented. The path forward will include the creation of BIM modules at Masters Level, to provide further opportunities for improving the skills in both project and strategic level of decision-making relevant to the implementation and management of BIM processes in the construction industry. The Department feels that BIM will be a major aspect in the future of the construction industry; the aim is to prepare Graduates with relevant skills and knowledge to be able to succeed within a continuously homogenous and collaborative industry.

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