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TITLE: Developing and embedding a BIM curriculum in build environment courses, the RGU experience.

YEAR: 2018

DEVELOPING AND EMBEDDING A BIM CURRICULUM IN BUILT ENVIRONMENT COURSES, THE RGU EXPERIENCE

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Abstract. Among The ambitions regarding BIM uptake across the built environment sector in the UK and arguably beyond may be tempered by a realpolitik shaped in part by interactions between Higher Education (HE) and professional practice. In September 2013, Education for the Built Environment (E4BE) was constituted as a strategic UK industry group by the Construction Industry Council (CIC) and Construction Industry Training Board (CITB). E4BE's strategic remit was to encourage professional institutions to extend their engagement with HE in collaboration with other stakeholders to add value to Higher Education's contribution to industry.

The BIM Academic Forum (BAF) comprises around 50 faculty members from UK universities and was formed to promote academic aspects of BIM, in particular, a "BIM Academic Framework". (HEA, 2013) BAF's articulated vision was to embed BIM learning within undergraduate and postgraduate Higher Education. BAF published an academic framework indexing BIM skills, knowledge, competencies and capabilities together with learning outcomes for BSc and MSc education levels in the UK.

In 2014/15 this framework, combined with research on international BIM curricula development, was used to develop a strategy to integrate collaborative BIM in the curriculum of all BE courses at RGU to be implemented over a 4 year degree cycle. This paper focuses on 4 key areas, namely:

- Presenting the BIM curriculum strategy, its rationale within the context of 4 professional accredited programs
- The implementation strategy of this curriculum to date and lessons being learned
- Reporting on 2 multidisciplinary collaborative BIM projects including feedback from tutors and students

- Presenting the outcomes of a survey conducted as part these 2 multidisciplinary projects focused on multidisciplinary collaborative working through BIM.

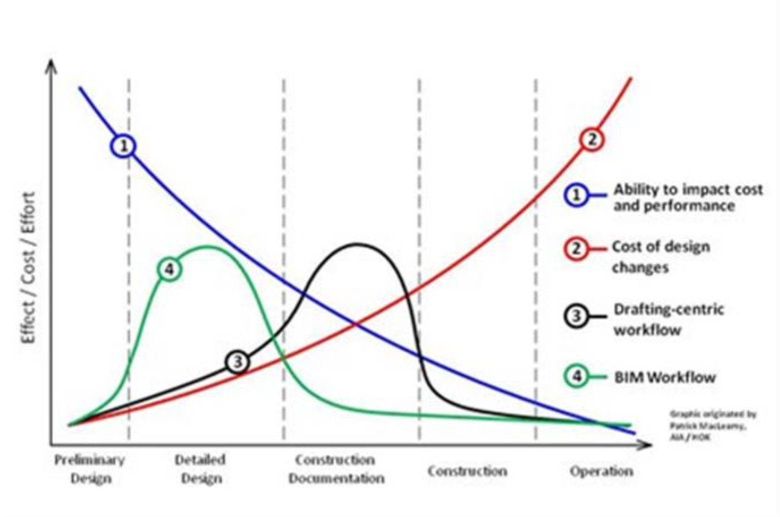
Keywords: Curriculum, BIM, Multidisciplinary, Collaboration, Workflow, Data.

1. Introduction

When this project was initiated in 2013 the debate on Building Information Modelling (BIM) had been steadily growing over the previous few years, especially following the British Government's intervention with its BIM Report and Government Construction Strategy (GCS) both published in 2011. The impact of these two documents on the construction industry had been and continues to be significant, and ultimately meant that all public sector spending will be channelled through a supply chain that is compliant with BIM level 2, now a reality. The Bew-Richards maturity diagram defines 'level 2' as file-based collaboration and library management. The drivers behind the Government 'push' are to achieve significant improvements in cost, value and carbon performance, as has been cited by the industry for some time (see Latham (1994), Egan (1998), Wolstenholme, Andrews et al (2009). In addition to the challenge of up-skilling the current work force, this has significant implications for higher education in developing future built environment professionals with the necessary skills to work in new ways, beyond their traditional disciplines. (BAF 2013) The BIM Workflow diagram in Figure 1 illustrates the savings in terms of time, cost, and efficiency of workflow through the design and construction stages of a project. In addition, it is recognised that Higher Education Institutions (HEI) will have to work with professional bodies in addressing new requirements in the accreditation of courses. It is important to note that all BE professional bodies have endorsed this view with the RIBA taking the lead with the new plan of work 2013 mapped against BIM workflows. (RIBA 2013) Since 2013 a series of BIM related standards have been published by the UK and Scottish governments to facilitate full implementation by the 2016/17 deadlines. PAS1192 versions 2,3,4,5 are examples of these standards to govern project data within the context of BIM and whole life cycle of an asset.

Since the publication of its construction strategy report in 2011, the government has set up a number of task groups to promote the implementation of its BIM strategy. This includes, amongst others, the training and education task group which has representation covering HEI, training organisations and bodies such as construction skills and Construction Industry Council (CIC).

The aim has been to bring together education and training stakeholders to debate how to best support upskilling and industry graduates of the future.



-Better ability to impact cost and performance
-Solving potential construction issues at design stages
-Potentially seamless collaboration
-Better workflows and project documentation
-Better communication

Figure 2. BIM v traditional workflow

2. Context

The Scott Sutherland School of Architecture and Built Environment (SSSA&BE) is one of few schools in the UK where most of the Built Environment (BE) disciplines are taught side by side sharing both human and physical resources. The question of Interdisciplinary teaching has been debated for a long time and occasionally attempted but with little real lasting effects. The debate remained theoretical, limited to some shared teaching, and largely a wish arguably reflecting the state of the BE professions.

In 2013/14 part of the preparation for its 5 yearly Institution Lead Subject Review (ILSR) coupled with the forthcoming move to a newly purpose built accommodation, the school decided to put multidisciplinary collaborative teaching on the agenda as one of the main goals. A key parameter used to drive the structure of the debate and guide the outcomes was that each discipline taught should maintain its identity and professional integrity. Any multidisciplinary curriculum would be implemented on a collaborative basis to add strength to each discipline and enhance the relationship between the disciplines.

The ongoing debate, nationally and internationally, on BIM coupled with the recently implemented UK government legislation have lead most education institutions to rethink at least the relevant parts of their BE courses curricula. The objective is to explore how to integrate collaborative BIM in their curricula. Given the importance of the impact on both teaching and graduate employability, the debate on multidisciplinary collaborative teaching has used BIM as a catalyst to try to achieve tangible outcomes and respond to the needs of the professions and the market in the spirit of breaking the silos and increase collaborative working. This project is driven by the following objectives:

- Collaborative working as an industry goal
- Government legislation mandating collaborative BIM from 2016/17
- Buy in by all relevant professional bodies
- Keep up / lead in ICT/BIM understanding and skills
- Tangible results that are meaningful to our courses and graduates

3. Mind the Gap: BIM implementation strategy and course curricula

3.1. BIM AND THE PROFESSIONS

The BIM Framework, a collaboration between the Higher Education Academy (HEA) and BIM Academic Forum (BAF), published an index of BIM skills, knowledge, competencies and capabilities with the endorsement of all BE professional bodies. (Fig. 1) The operation category’s focus is on learning the necessary skills to operate collaborative BIM software; developing awareness and data file exchange standards. The management category’s focus, however, is on professional and middle management issues to include BIM awareness, collaboration, standard methods and procedures, value and industry challenges. All these points could be easily described as of a multidisciplinary nature as they cut through professional boundaries.

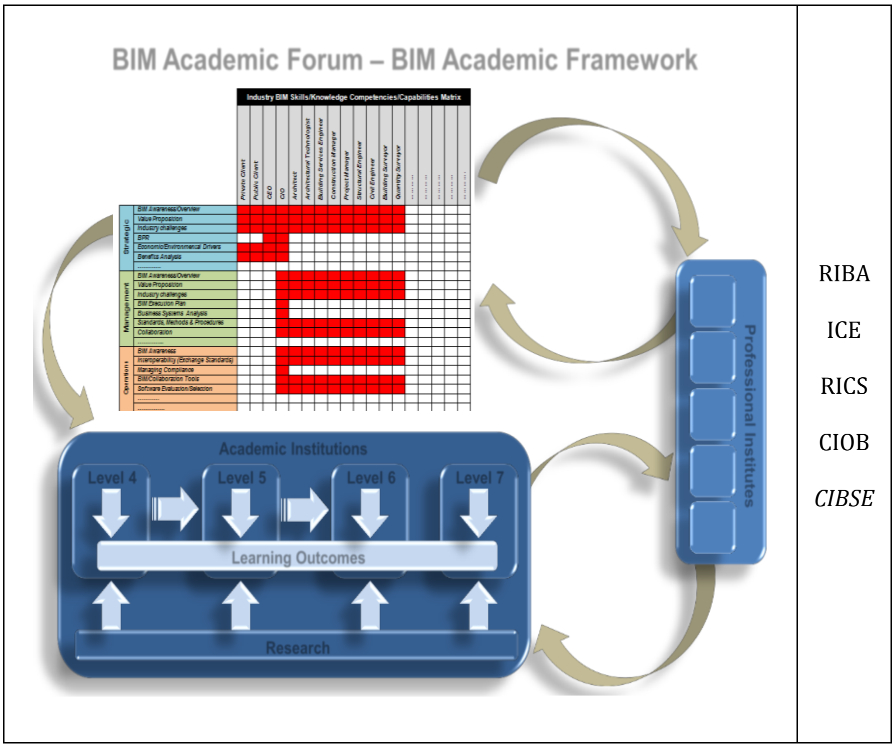


Figure 1: BIM Academic Framework

A quick examination of SSSA&BE courses revealed that they all fall under the operation and management categories, the former for the lower years (1 to 2-3) and the latter for the upper stages (3-4 to 5). In session 2013/14 Architecture and Architectural Technology (AT) students largely met the operational category and were taught the software skills with a good degree of application in the first 3 years of their respective courses. Surveying and Construction Management (CM) fell short on these skills. Overall awareness was very briefly introduced with limited theoretical underpinning and hardly any instructions were provided on data exchange and interoperability. BIM awareness was covered at an introductory level on AT and Architecture courses. Industry challenges were invariably covered by all courses at varying degrees in a number of Professional Practice and Management modules.

3.2. BIM TEACHING STRATEGY AND IMPACT

The IT tools and CAAD skills taught within the various curricula at the SSSA&BE in 2013/14 are summarised in Table 1.

TABLE 1. IT / CAAD provisions in 2013/14

Tools	**Theoretical underpinning**	**Year & Course**	**Modules**
Introduction to IT and basic software (AutoCAD 2D /Photoshop…)	Yes (basic)	Surv1 / AT1 / BS1 / Arch 1	Scholarship skills I. Studies (AT) Intr. To B. Design
Revit	Minimum	AT2 / Arch 2	Design Studio I. Studies
Environmental Analysis software: IES / SAP / Green studio… (2D, 3D)	Yes (limited)	AT2 / Arch 3 AT3 / AT4	I Studies Design Studio
Construction Management software (2D) Asta Power Project	Minimum	QS/BS 4	Project Management I Studies
Surveying estimating software (2D) BCIS	Minimum	Surv2 / Surv3	Bill of Q
Introduction to BIM	Yes (basic)	Arch stage 6	P Practice & Management

It is apparent that the tools taught have a direct correlation to the area of the curriculum within each discipline e.g. Autodesk Revit for AT and architecture, BCIS for surveyors and Asta Power Project for Construction Management etc. This correlation can be interpreted as singular in that it only focuses on the discipline and very little is done cross-disciplines such as an integrated module or integrated delivery of these skills. Information gleaned from course leaders and tutors suggested that although the practical skills are being taught, the relevant Knowledge and understanding is in need of major improvement. For example, the shift from AutoCAD to Revit was implemented in 2009 but very little if any lectures on BIM and the wider context of 3D modelling and data management were coherently taught. Limited teaching using some aspect of collaborative BIM had been attempted by the AT course.

4. Bridging the gap: strategy and Impact

The methodology used in this project was based on a number of sources of information and tools of analysis both internal and external. Focused discussions with course leaders and key teaching staff were used to glean discipline specific information and explore the concept of collaborative learning from each discipline's view point together with aspirations and most appropriate methods of delivery. Literature sources were used to provide context, legal framework, professional bodies' requirements and professional practice trends in the area of BIM and associated skills.

BIM curriculum and associated mapping and impact assessment tools developed by BAF in association with HEA were used as a guide to assess current provisions and future requirements within the school.

Table 2 uses the HEA Index to map the impact of the proposed BIM curriculum on current and target provisions within the school. Yellow indicates a level either already achieved or could be easily achieved by all disciplines in the School. Red, however, indicates the level to be attained by all disciplines within the next 3 years to meet the target date of government BIM mandate (2016/17).

The impact on curricula in 2013/14 was minimal in the first instance and any minor adjustments could be accommodated with existing IT/CAAD provisions except for Surveying and CM. The latter courses needed to be brought up to the minimum threshold already achieved by AT and Architecture. To meet the BIM level 2 target, however, substantial adjustments needed to be done to key modules which may include embedding assessments in projects, delivery of a knowledge and understanding programme and practical interdisciplinary sessions. Course structure was not affected except minor key module adjustments of teaching plans or instruments of assessments. The biggest impact identified was on staff development and IT infrastructure. The curriculum research gap was found to be adequate within the school as many research active staff in this area were already embedding most of their research into teaching, mostly at master level (MSc courses).

TABLE 2. BIM Teaching Impact Index 2013/14

	BIM Level			
	Absent	**Aware**	**Infused**	**Embedded**
BIM descriptor	BIM is a nice research area but should not affect what and how we teach. Our students do not need to know about BIM.	BIM is a nice research area but should not affect how we teach. Our students should be aware of BIM and how it might impact their future.	Students should understand how BIM will affect their future and have chance to learn BIM in a discipline & multi-disciplinary context.	BIM is so important it should become the 'vehicle' for our students' learning experience. Teaching should be enabled by the BIM model.

Curriculum	No change	Key modules are identified and BIM knowledge incorporated.	Target modules identified for a BIM review. BIM impact identified in all areas of the curriculum but BIM use restricted to a few.	Full curriculum review to allow every module to identify changes required for delivery through a BIM model.
Structure	No change	No change	Structural review needed but impact on current structure likely to be minimal.	A complete review of structure to enable the BIM model to be the driver/vehicle for learning.
Staff	No change	Staff in the key modules will need an understanding of BIM and how it impacts on industry.	All staff require knowledge of BIM and how it is impacting industry. Some staff need full competence in use of BIM.	All staff would need to be fully competent in the use of BIM and understand how BIM is impacting on the industry.
Infra-structure	No change	No change	Significant investment required. BIM labs needed and some delivery space suitable for BIM enabled learning.	Significant investment in infrastructure required. BIM labs and delivery space sufficient for BIM being the learning vehicle.
Curriculum - Research gap	Can be large	No change	Has to be small in some areas but with some flexibility.	Has to be small for all areas of the curriculum. Genuine integrated direction between research and curriculum/delivery
Yellow: current status Red: to be reached by 2016/17 Ref: Williams and Lees, 2009				

5. Making it work: implementation and other stories

BAF/HEA published a level learning mapping of a BIM curriculum that would meet the requirement of level 2 BIM and beyond. This mapping was utilised to map SSSA&BE disciplines provisions in 2013/14 (Table 3) indicating levels already being met and any deficiencies. It also suggested the method of delivery, method of application / assessment and the vehicles of delivery. Collaborative teaching was also highlighted where applicable.

It is clear from this mapping that only the practical skills (green font) were being taught with some minor shortfall at upper stages. The practical skills (red font) were not delivered in any coherent manner although some disciplines may have covered some aspects in isolation within particular modules. Knowledge and Understanding (red font) was also not taught in any coherent way also the concept of collaboration may have been applied elsewhere such as group work but within the same discipline.

The delivery vehicles column (blue font) identified the modules within each discipline where teaching could take place including common teaching. It was identified that within these modules that collaborative links could be achieved through theoretical lectures, skills workshops, projects and integrated assessments.

TABLE 3. Mapping of BIM curriculum

Level	Knowledge and understanding	Practical skills	Transferable skills	Delivery vehicle
	Undergraduate			
4/7	- importance of collaboration - the business of BIM -common lecture	Introduction to technology used across disciplines -AutoCAD/Revit/ Photoshop workshops	BIM as a process/technology/ people/policy - A common lecture with a workshop collaborative task	- Communication skills module (BE) - IT workshops (All) - Design studio (Arch)
5/ 8-9	-BIM concepts & construction processes -stakeholders' business drivers -supply chain integration - Series of lectures to accompany workshops	-use of visual representation - BIM tools and applications - attributes of a BIM system - Revit workshops for all courses	- value, lifecycle and sustainability - 'software as service' platforms for projects - collaborative working - communication within interdisciplinary teams - short inter-disciplinary collaborative project -Application in a project	- Design studio - Design Technology - Bills of quantities - Environment and Services
6/ 10	-BIM across the disciplines -contractual and legal frameworks/ regulation -people /change Management	Technical knowhow: -structures and materials -sustainability -Application workshops: -Environment assessment software - Costing software	Process/management: -how to deliver projects using BIM -information and data flows -BIM protocols/EIR - Lectures followed by an interdisciplinary	- Design studio (Arch stage 5) - Design Tech / Int. studies (AT & BS) - QS?

	- A series of lectures on topics with demonstrations	- Modelling	project using a central/federated data model	
Colour coding: - Black font: BAF / HEA mapping - Red font: method of delivery & method of assessment (partly/not met) - Green font: Delivery being met or could be easily met next session - Blue font: vehicles of delivery (modules) where learning could be embedded. - Level: English and Scottish education levels				

The above mapping of the school's undergraduate courses curricula together with an assessment of physical and human resources culminated in a BIM curriculum proposal which was approved by the school for implementation. Knowledge and Understanding, Practical Skills and Transferable skills were mapped against methods of delivery, course relevance and vehicle of delivery as illustrated in Table 4.

TABLE 4. Summary of proposed curriculum

Year		Delivery method	Program	Delivery modules	Observations
	Knowledge & Understanding	shared lecture on: - importance of collaboration - the business of BIM	All	Communication skills module - Design studio (Arch)	
1	Practical skills	Existing AutoCAD/ Revit/ Photoshop workshops on: -Introduction to technology used across disciplines	All	- IT workshops (All)	
	Transferable skills	A common lecture with a workshop collaborative task on: -BIM as a process/ technology/people/ policy	All	- Design studio - Intr. to B Design	
	Knowledge & Understanding	- Series of lectures on -BIM concepts -construction processes -stakeholders'	All	Part of Revit workshops	
	Practical skills	Revit workshops		- Design studio	Customised tasks within

2		-use of visual representation -BIM tools and applications -attributes of a BIM system	All	- Design Technology - Integrative Studies - Environment and Services (IES)	the relevant module for each discipline
	Transferable skills	A short interdisciplinary collaborative project -collaborative working -communication within inter-disciplinary teams	All	- Design studio - Design Technology - Integrative studies	
	Knowledge & Understanding	Lecture(s) on: -business drivers -supply chain integration	All	-Management -P Practice	
3	Practical skills				
	Transferable skills	-Application in a course specific project -'software as service' platforms for projects -value, lifecycle and sustainability	All	-Design Studio -Integrative studies	
	Knowledge & Understanding	A series of lectures on topics with practical demonstrations -BIM across the disciplines -contractual and legal frameworks/ regulation -people /change Management	All	-Integrative studies -Building Technology -Design Studio (Tech support)	
4 / 5	Practical skills	Advanced application workshops on - Environment assessment software - Costing software - BIM Modelling on Technical knowhow: -structures and materials -sustainability	All	-Integrative studies -Building Technology -Design Studio (Tech support)	Customisation by discipline to provide context to each course
	Transferable skills	Lectures followed by an interdisciplinary project using a central/federated data base to demonstrate: Process/management:	All	-Integrative studies -Building Technology -Design Studio (Tech support)	An elective may be used for advanced learning of BIM process

	-how to deliver projects using BIM -information and data flows -BIM protocols/EIR
	Colour coding: - Black font: BAF / HEA mapping - Red font: method of delivery & method of assessment (partly / not met) - Green font: Delivery being met or could easily BE met - Blue font: vehicles of delivery (modules) where learning could be embedded.

A colour coded tracking methodology has been used to monitor progress of implementation over the last 3 years as summarised in Tables 5. Green indicates over 90% completion, yellow over 50% completion and red not attempted as these levels are perceived as not appropriate to non-BIM dedicated courses and will have a detrimental effect on professionally accredited course if fully implemented.

TABLE 5. BIM Teaching Impact Index 2016/17

BIM Implementation level: 2016/17				
	Absent	**Aware**	**Infused**	**Embedded**
BIM descriptor	BIM is a nice research area but should not affect what and how we teach. Our students do not need to know about BIM.	BIM is a nice research area but should not affect how we teach. Our students should be aware of BIM and how it might impact their future.	Students should understand how BIM will affect their future and have chance to learn BIM in a discipline & multi-disciplinary context.	BIM is so important it should become the 'vehicle' for our students' learning experience. Teaching should enabled by the BIM model.
Curriculum	No change	Key modules are identified and BIM knowledge incorporated.	Target modules identified for a BIM review. BIM impact identified in all areas of the curriculum but BIM use restricted to a few.	Full curriculum review to allow every module to identify changes required for delivery through a BIM model.

Structure	No change	No change	Structural review needed but impact on current structure likely to be minimal.	A complete review of structure to enable the BIM model to be the driver/vehicle for learning.
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Infra-structure	No change	No change	Significant investment required. BIM labs needed and some delivery space suitable for BIM enabled learning.	Significant investment in infrastructure required. BIM labs and delivery space sufficient for BIM being the learning vehicle.
Curriculum - Research gap	Can be large	No change	Has to be small in some areas but with some flexibility.	Has to be small for all areas of the curriculum. Genuine integrated direction between research and curriculum/delivery
Yellow: over 50% complete Red: Not started for strategic reasons Green: over 90% complete Ref: Williams and Lees, 2009				

As of 2016/17 the level of BIM Curriculum implementation may be summarised as follows:
- All courses now complete a minimum threshold of Revit training including BIM awareness
- All courses complete a practical skills in data and file manipulation / management within a central model
- 2 BIM modules (BIM theory and BIM Practice) are delivered at postgraduate level to achieve awareness and application of level 2 BIM
- 50% of staff have full BIM awareness and practice BIM partially within the context of their discipline
- Investment in hardware and software completed to level 2 BIM requirements and further investments still needed for level 3 and beyond
- Integration of BIM level 2 knowledge and Understanding within Professional Practice and Management modules is complete

- BIM process management theory is delivered where appropriate but application remains an ambition.

6. The common thread: collaboration, collaboration, collaboration

This section summarises 2 BIM multidisciplinary projects carried out over the last 2 academic sessions part of the implementation of the new BIM Curriculum seeking collaborative learning amongst the various BE disciplines.

6.1 BIM COLLABORATIVE PROJECTS 1 AND 2

The aim of these 2 short projects was to start developing collaborative working skills through BIM in anticipation of UK/Scottish government legislation and to reflect ongoing changes to work practices in the BE professions. These pilot projects were run over two consecutive academic sessions 2015-16 and 2016-17 to test how it could be inclusive of all cohorts. The projects were open to a selection of students from the 4 disciplines within the school to work in groups on an existing BIM model. Each group had to undertake a number of tasks including making design/construction decisions then incorporating them into a central model. The tasks per discipline were as follows:

Architecture team (years 2 & 3): redesign the external envelop (facades, roof) of the building i.e. materials, colours, textures; redesign the landscaping of the site including access, green and hard surfaces, steps, ramps, etc.

Architectural Technology (years 2 & 3): Procure new doors and windows (both internal and external) to improve the thermal performance of the building, carry out an energy assessment of the building, and carry out a lighting assessment.

Surveying and Construction Management (years 2, 3 & 4 AT in a supporting capacity): embed unit cost in the following materials/ components: doors, windows, furniture; using the 3D model produce a material schedule of the above components.

A workshop was designed to host 20 interdisciplinary students to collaborate on one project; the project was modelled to an extent using Revit. The workshop started by briefing the students on the workshop aim and objectives, the organisers gave a short talk about collaboration and BIM, what are the benchmarks of UK industry with a rough plan for the workshop.

Then students were asked to work in groups of 5, each group has a title of Architecture, Architectural Technology or Surveying. Each group has to achieve a specific task. Each group worked on one model, and then at the end of the workshop the models were merged and presented to the students with a brief discussion on the result, their experiences and technical difficulties.

6.2 STUDENT SURVEY AND FEEDBACK

Each BIM project programme included a student staff feedback session then followed by a questionnaire to all participating student. A questionnaire was designed to ask participants to reflect on their specific experience within their group and other groups.

A summary of the feedback is given below.

Student feedback

- All students enjoyed working in a collaborative multidisciplinary groups
- Architecture students identified their lack of practical experience using BIM models and would like a practical element be embedded in their design studio projects
- AT students seemed to some extent familiar with the practicalities of BIM software but struggled with performing environmental analysis due to network failure in the first iteration due to firewalls
- Surveying students were to a disadvantage since only recently they had started learning Revit/BIM software but with the support year 4 AT they saw the relevance to their disciplines
- Stage 4 AT had sufficient expertise to help all other students and staff set up the protocols of the collaboration
- All students agreed that similar projects should be repeated and extended to bigger cohorts.

Staff observations

- An experienced BIM coordinator (AT graduate)
- The project was a good taster for a limited number of students
- Students had, in the first iteration, very limited awareness of design management, BIM standards and protocols. In the second iteration, better understanding was clear and a number of students, particularly AT and Architecture, had a handle on basic BIM protocols such as synching of models and federated model rights
- The University IT network had major technical limitation in setting up a Common Data Environment (CDE) in the first iteration. In the second, however, with the support of IT engineers who created a special area on a University server and modification to access rights and security set up, the BIM project run smoothly.
- Limitation of staff expertise in the practicalities of BIM i.e. setting up protocols and manipulating project data in the first iteration which were remedied by an external BIM coordinator in the second iteration.

7. Post-Workshop Questionnaire

A BIM multidisciplinary project questionnaire was designed to understand the academic context whereby three multidisciplinary groups of students used BIM workflow in order to reflect back on their experience despite the fact that BIM was not an integrated part of their project model as yet. The questionnaire was structured into two main sections; the reflective part, and the active part of experiencing BIM.

7.1 FINDINGS

The reflective part focused on the workshop advantage and disadvantages by asking them multiple questions. Students agreed that the main advantage of such workshops was having a better understanding of how Revit (3D modelling software) would work with multiple users simultaneously.

Most of the students agreed that the workshop's disadvantages were mainly: its (short) duration, intensiveness in terms of its tasks, new software program for some, and technical and network constraints. It is possible that the students' prior knowledge of Revit detracted them from the collaboration aspect. Conversations were mainly focused on how to complete certain tasks rather than using the model for designing or testing ideas.

The participating students responded that their working flow they had used was mainly influenced by the studio tutors (22%), equally influenced by their personal skills (19%), and studio skills (19%). They were also equally influenced by their own approach to BIM (16%), and the type of task undertaken (task characteristics) (16%), with less influence from the systematic evaluation of the model (5%), or any previous placement skills (5%).

The participating students' answers revealed that using BIM workflow was useful to them in looking at more than one aspect (options) of the task and collaborating with other students more effectively (23%). Speeding up the systematic evaluation of their group work (16%) and looking at more than one way or method to solve the task (16%). However; overcoming the design task uncertainty and prompting peer learning (11%) contributed poorly.

Revit experience influenced one or more of the following design tasks. It has influenced the way students communicate through design (27%), the way they document design solutions (19%), the way they make decisions (19%), and the way they solve design problems (19%), nonetheless; some of the students indicated that using BIM workflow influenced the way they think about design (16%).

Most importantly, students were asked which way they would prefer to learn BIM. A significant percentage stated that they prefer to learn BIM integrated within their existing courses (37%), with an equal percentage of participating students stating that they prefer the combination of learning BIM within existing courses and within multidisciplinary modules (37%). However; some of them responded that they prefer to learn BIM in an independent training course (26%).

Students' responses were very positive about the workshop and the gained skills; some of them mentioned 3D modelling techniques, energy and lighting assessment through Revit programme without the use of any external (specialised) programs. They also learned about the synchronising of models. The general consensus of the results show that students found the workshop very useful in terms of getting the actual experience of using Revit in a collaborative workflow. Peer discussions were also mentioned as a significant gain that has significantly improved their knowledge.

Finally, the participating students made some suggestions on how to improve and plan for the next workshop. These included more practical hands-on experiences, and to make the outcomes a worthwhile part for the learned skills. Some also suggested having more than one workshop (a number of sessions) across all courses, as they felt that the exercise was short in its nature. The students also mentioned the value of having people from industry who have experience working with collaborative models to guide everyone through the workshop. Other students suggested having more defined tasks with a product library with deep specification, especially thermal properties in order to be ready for an environmental analysis. One other suggestion was to structure the workshop in a way that is similar to simulated practice.

8. Conclusions

The following conclusions are drawn from the various discussions and data presented above. The implementation of a BIM curriculum at SSSA&BE was successful as far as raising awareness of BIM and raising BE students' BIM practical skills to a near level 2 threshold. Courses like Architecture and AT demonstrated better engagement and reached advanced levels of skills and understanding given the design / technical design nature of the courses relative to Surveying and CM. Acquiring a common BIM threshold helped interdisciplinary and multidisciplinary collaborative working beyond these 2 pilot projects, particularly in design studio and integrative studies projects. Furthermore, increased engagement with BIM enabled specialist software such as Asta Power Project for CM, IES for AT and Architecture etc. was noticeable.

Embedding the proposed BIM curriculum fully was not practical mainly due to professional bodies mapping requirement which tended to lag behind their public discourse. However, stepped and contextualised integration across curricula was possible but required adjustment.

Two major difficulties were encountered, namely staff resistance to change and appropriate infrastructure. A good number of teaching staff perceived BIM as another CAAD tool and failed to appreciate its extent both academically and in practice. A BIM CPD programme was devised for staff with less than 50% take up over 3 years. The IT infrastructure obstacles needed to be tackled. First large data, processing power and annual software updates put increased demands on hardware which very quickly started to struggle and needed an upgrade which does not often fall within the replacement schedule of the University nor the high costs involved. Moving beyond level BIM requires serious investment not IT hardware and appropriate IT specialist support both at school and University level.

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