A CRITICAL REVIEW OF BIM ASSESSMENT PRACTICES FOR A CONSTRUCTION MANAGEMENT MODULE

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ABSTRACT

The three pillars of education are based on: i) curriculum – what is taught, ii) pedagogy – how it is taught and iii) assessment – assessing what is taught. The final educational component of 'assessment' is the main focus of this paper. The authors will seek to demonstrate the various purposes of assessment through utilizing the visual, parametric and cross-discipline co-ordination attributes of Building Information Modeling on a Construction Management module. The principle objectives of this paper is to identify both the challenges of assessing students in a real-time learning environment and emphasize the benefits of constructing a virtual model designed to harmonize the learning outcomes. The theory of assessment is based on the process of evaluating how much the student knows in order, to form judgments which, in turn, are to be used in *decision making.* The technique used to investigate student learning difficulties and improve the educators teaching methods was reflected in observation as a necessary tool to increase the validity and reliability of the assessment procedures. Through providing a BIM model based on intelligent object architecture and shared information (collaboration) the findings of this paper highlights the positive student driven learning path which, in turn, improves the teacher's feedback analysis.

Keywords: assessment, building information modeling, feedback, observation, virtual models

1. THE ROLE OF BIM WITHIN THE UK CONSTRUCTION INDUSTRY

In 2012, HM Government published a strategic document assessing the ambitions of their three part action plan on public sector BIM adoption: 1) fully commit to the existing BIS BIM program to create critical Mass, 2) aim for growth, and 3) help create the future by continually developing their capabilities (Blackwell, 2012). With regards to analyzing part 1: fully commit to the existing BIS BIM program this part refers to the 'BIM Industry Working Group strategy document'. The BIM Industry Working Group was invited by the Cabinet Office to review the construction and post-occupancy benefits of BIM (Building Asset) Information Modeling and Management) for use in the UK building and infrastructure markets. In March 2011, they published a strategy paper listing six specific recommendations of which this author connects two of them directly to education: i) take progressive steps; a five year period has been requested of the supply chain to allow for technology, training, legal, and cultural changes to be effectively communicated and adopted on both supply and client side, and ii) have a clear target for the "Trailing Edge" of the industry; this refers to recommending targets such as, by 2016 all government projects will have to use "level 2" of the maturity model (BIS, 2011).

Baldwin (2011) highlights the benefits of the UK government program to introduce BIM into all public sector projects by 2016 for example; in the context of rising asset management costs, the government aims to reduce whole-life costs by 20% with its overall trajectory to reduce carbon emissions by 80% by 2050. As an anecdote to the legacy of BIM; Baldwin identifies that firms that are not yet BIM-proficient are preparing for change. In order, to comprehend what change this might be? Sinclair (2012) outlines the RIBAs plan of work with reference to "Level 2" BIM, for example; use of the architect's information for the environmental modeling in the early schemes, early analysis of the design model to determine structural stability, real-time integration of the model data into cost planning model, development of the structural frame model by the fabricator to create connection designs and use of the curtain walling contractor's model to develop CADCAM files, allowing rapid shift from design to fabrication.

However, it would be difficult to argue against the UK Government strategic adoption plan to provide a digital built BIM Britain in order to sustain UK leadership especially taking into consideration such recent events as the 'Construction of The New Ark Hotel' in Xiangyin County, Changsha City, China: 170,000 square foot, 30 Storey hotel turn keyed in 15 days using pre-fabricated modules, diagonal steel bracing, filtration system with 20 times purer air inside than outside, and with stand a 9.0 magnitude earthquake (Rosenfield, 2013).

The main focus of this paper is to discuss the potential of using BIM as an assessment application, subjectively highlighting various assessments procedures/feedback methods and learning objectives that will embrace the adoption of change within the UK education system in order to align assessment techniques with the UK government's plan. The paper will also identify the assessment technique developed by one of the authors on 37 attendees (mixture of construction managers, quantity surveyors and architects) at a Chartered Institute of Building (CIOB) event held at Anglia Ruskin University (UK).

2. BIM AS AN EDUCATORS ASSET

2.1 The Problem Statement

The principles of construction concepts identified by Radosavljevic and Bennett (2012) are embedded in the 'Human Reasoning' of construction relationships. Radosavljevic and Bennett recognize that effective communication is important to most human actions but is extremely difficult to achieve due to difference in understanding. This is mainly caused by the inappropriateness of achieving the following features: a) the communicated matter must exist in one organization, b) the communicated matter is turned into a medium capable of being transferred to another organization, c) the medium is moved from the originator to the receiver, and d) the receiving organizations detects the information in the medium, the receiver attempts to understand the information.

These failings in practice can also be contributed to the weakness in teaching Construction Management. In order, to develop a curriculum that involves construction relationships new innovative approaches must be introduced to form a multi-facetted range of relationships. In practice management teams learn from feedback and work as an organization to improve performances. With this in mind the authors suggests that teaching environments should re-enact these deliverables through virtual environments and provide suitable feedback that can be safely controlled and tested prior to practical experience.

2.2 Teaching BIM for Construction

Kang and Ryoo (2012) emphasize that teaching students how to use BIM for marketing, clash detection, and visual representation of the construction sequence is a major semester challenge. They acknowledge that challenges will exist because the students will have to understand how to create an object-based 3D model building and combine it to a construction schedule in order to visualize the construction sequence in a 4D world. Kang and Ryoo drafted a specific five point plan incorporating such methods as combining the 3D model and construction schedule to produce a 4D model representing the construction sequence in order to personalize the students learning experience by appreciating various applications. The emphasis of this type of learning 'pedagogy' was its ability to allow necessary skills to develop. Kang and Ryoo validated this process by citing

Wolf (2010) "personalized learning is the way in which our best schools tailor education to ensure that every pupil achieves the highest standard possible". In evaluating this new method of teaching they designed a class project as an assessment technique through engaging students to read the plans provided by a class sponsor, and create a 3D model. These models were in turn used to develop a 4D model incorporating activities, identifying critical paths and calculating the start dates and end dates of these activities.

In order, to define professional development Yori (2012) cites the dictionary.com definition "the advancement of skills or expertise to succeed in a particular profession, especially through continued education". In further itemizing this statement Yori categorizes professional development as education that can take place in the form of mentorship, study and research or personal experience as it is inextricably tied to knowledge, accomplishment and success. However, he does stipulate that classes which use BIM to focus on application functionality without providing the "big picture" (perspective of the overall BIM process) will create an absence of applied knowledge "the need to learn the correct tool in context of the specific professional goals". Yori advocates his philosophy on how adults learn through emphasizing that "adult learning motivation is at its highest when an individual can relate the material to his or her experience. What could be more motivating than a direct correlation to one's day-to-day responsibilities? What if a relationship could be established to BIM and increased efficiency? Increased project quality? How about innovation"?

3. ASSESSMENT OF LEARNING TECHNIQUES

3.1 Assessment

Ollin et al. (2010) recognizes that there are three distinct types of assessment which are dependent on the stages they are used and for which purpose. These specific types' summative, formative and ipsative are interchangeable and their structure provides a useful framework for analyzing assessment processes. Summative assessment – the use of summative assessment is generally associated with an award of qualification such as a certificate. This type of assessment can also provide 'feed forward' (ensuring that feedback is embedded in day-to-day learning activities) in anticipation of the next assessment. Formative assessment – takes place during a course and is an integral part of learning, formative feedback (known as feed forward) provides guidance between current and desired outputs. In many cases a short written test may be required accompanied by feedback. Ollin et al. identifies four key characteristics of formative assessment: 1) assessing feedback with the intention of making future adjustments, 2) providing teachers with data on how their students are progressing, 3) allowing students to identify their performance, and 4) evaluating students' needs or barriers to learning.

Ipsative assessment – with this form of assessment the students starting point is identified and targets are benchmarked against future progress. This type of technique allows the student to reflect on their own learning goals independently of the teacher. The structure of this method sometime involves 'scaffolding' such as checklist and self-assessment pro-formas. In summary, key skills such as evaluating how to learn and self-regulate encourages the students to develop the ability to direct their own learning style.

3.2 The Purpose of Assessment

Scales (2008) categorizes the main purposes of assessment into five key areas; i) initial assessment, ii) diagnostic assessment/testing, iii) formative assessment, iv) summative assessment, and v) ipsative assessment. Scales analogy of these assessments is as follows; initial assessment - relates to information gathering with objectives promoting career intentions. However, the learning styles associated with this form of assessment are generally meaningless unless they are adequate addressed to inform planning and delivery of learning. Diagnostic assessment - these types of assessment relates directly to testing the learner's ability to learn key skills for example; literacy and numeracy. Formative assessment - can be considered as one of the two main types of assessment the other notably summative. In comparison to summative assessment formative is a teaching and learning experience that is aimed at promoting learning whereas the latter concentrates on making judgments against standards. Scales reviews the epistemology of assessment by citing Black and Wiliam (1998) five main factors of assessments: i) the provision of effective feedback to learners, ii) the active involvement of learners in

their own learning, iii) adjusting teaching to take account of the results of assessment, iv) a recognition of the profound influence assessment has on the motivation of learners, and v) the need for learners to be able to assess themselves and understand how to improve. These five challenging factors can be connected to formative assessment with feedback being directly linked to construction management relationships (see section 2.1). With regards to adjusting teaching criteria acknowledgement of techniques used in learning such as recall questions are adequate for checking progress but not suitable for motivating learners. Summative assessment are a necessity to validate learning outcomes however, it is the authors view that BIM can have a profound impact on the process of qualifying these grades through a virtual environment. By simulating virtual model to forensically analyze elements of construction the student will be able to comprehend the feedback in a more intuitive manner thus leading to a self-learning experience.

3.3 The Conflicting Purposes of Assessment

Table 1: Conflicts of assessment for BIM Course (Adapted from Bloxham and Boyd, 2007)

Principle	Link to purpose of assessment	Strong	Medium	Weak
Validity	Student learning, certification		With regards to a BIM course a certificate would be of practical benefit, identifying to a potential employer the level of the students skills set.	
Reliability	Certification, quality assurance	The design of the BIM course for construction management would emulate real life practice environment in a virtual world.		
Effectiveness	Student learning, lifelong learning		Effectiveness has a link to validity and sometimes the grading function is overemphasized in comparison to learning whereas a BIM module is a self-learning assessment.	
Comparability and consistency	Quality assurance			At the moment there is not a wide range of standard BIM courses in the UK and in order for consistency the Universities delivering such a module must form a standard.
Transparency	Student learning, quality assurance, lifelong learning	The information, guidance, rules and regulations on assessment for a BIM course would be easily transparent as BIM tools are themselves completely open to visual assessment and comments.		
Practicability	Student learning			As this is a novel idea and only has been tested on a short course (see section 4) there will be limitations based on trial and error, however the marking should be both a compilation of computerization and theory tests.
Equity	All purposes of assessment	The BIM course would allow the students to demonstrate their knowledge of construction techniques expressing their own diversity and intuitivism.		
Attribution	Certification		In order to identify clearly that the work is the students – over a semester they would undertake a short test (formative assessment).	

Bloxham and Boyd (2007) acknowledge that there are four purposes of assessment: 1) certification – as an award it provides a mechanism to differentiate between the different levels of achievement, 2) student learning – contributes to promoting learning and giving the teacher useful information in order to make changes, 3) quality assurance – provide evidence to employers, external examiners, inspectors that a standard has been reached, and 4) lifelong learning capacity – encourage students to continue to develop skills and knowledge for the workplace (these four purposes of assessment are highlighted in Table 1 'link to purpose of assessment' column). However, Bloxham and Boyd identify that some techniques provide reliable scores while others can be subjective due to various markers perceptions. They emphasize that different purposes should have different principles of assessment. These four conflicts are evaluated against eight principles as shown in Table 1. In conclusion and possibly a way forward each of the four conflicts should be performance based for example:

- Certification relates to validity, reliability, equity and attribution. Table 1 indicates this as two Strong and *two medium* for example; under the principle of validity the assessment of certification scored a medium with the following recorded statement "With regards to a BIM course a certificate would be of practical benefit" and for attribution assessment it indicates "In order to identify clearly that the work is the students" hence the score of *two mediums* etc.
- Student learning highlights validity, effectiveness, practicability, equity and transparency – the metric table indicates a score of three mediums, one strong and one weak.
- Quality assurance is associated with validity, reliability, transparency, equity, comparability and consistency – three strong, one medium and one weak.
- Lifelong learning emphasizes validity, effectiveness, equity and transparency – two mediums, and two strong.

Overall the performance metric table identifies that BIM courses do have potential but areas such as student learning and quality assurance require further attention.

3.4 Principles of Assessment for a BIM Course

In evaluating the benefits of self-assessment the purpose of the BIM module would need to have specific criteria upon which to base self-assessment, however this may lead to a lack of ingenuity on behalf of the students hindering their ability to think outside of the 'box'. Profiling is an analysis that requires one objectively recording their learning, development and assessment experience. The most prominent technique would be observation creating validity and reliability of the procedures and building a relationship between educator and student.

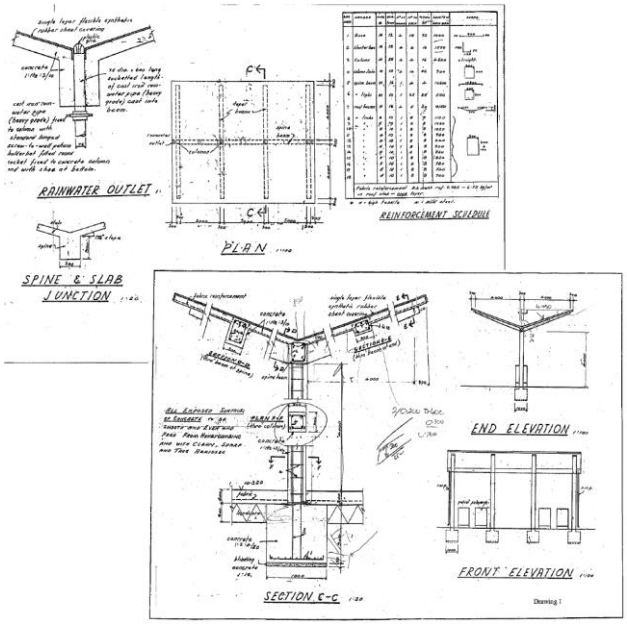

Figure 1: Two Dimensional Plan and Section Drawings of a Petrol Station

The future techniques applied for a BIM module would incorporate a mixture of the methods: summative, formative and ipsative because it allows the students to comment on both positives and negatives of the course which can lead to generating ideas to improve the module. The hypothetical course to be designed for Anglia Ruskin University (UK) would be based on the following steps:

- Step 1: convert two dimensional plans and sections (Figure 1) into 3D (design) BIM models (Figure 2 and 3),
- Step 2: develop a critical path method of planning based on these models in order to establish a program that itemizes work break down structure of tasks assigned to a Gantt chart,
- Step 3: analyze these BIM models and programs in a 4D (time) BIM model to establish program assessments for pre contract stages for example; tender period, cash flows, earned value analysis, resources, materials and plant utilization and cost impact etc.
- Step 4: the 3D models would be forensically investigated by the students in order to produce Bill of Quantities (BoQ) in a computer application either connected to the models or independently based on standard measurements such as the Civil Engineering Standard Method of Measurement 4 or New Rules of Measurement 2.
- Step 5: incorporate the materials and plant suppliers into the 4D model with market rates and likewise with the quantities recorded in the BoQ.

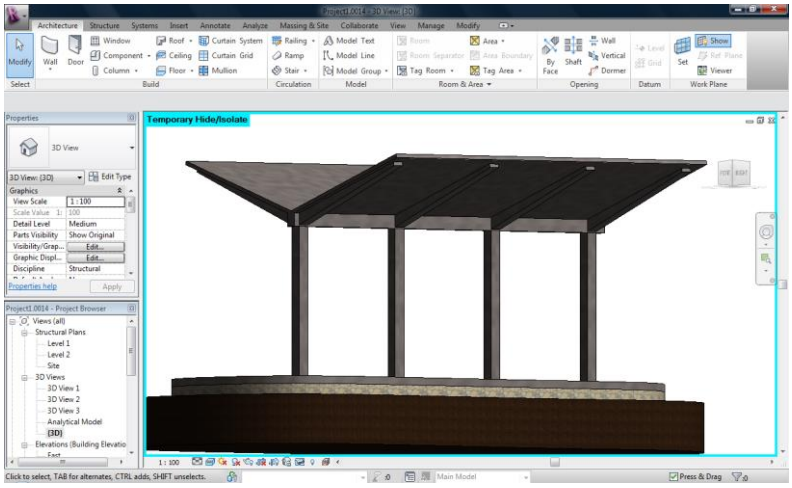

Figure 2: Petrol Station (3D Revit model)

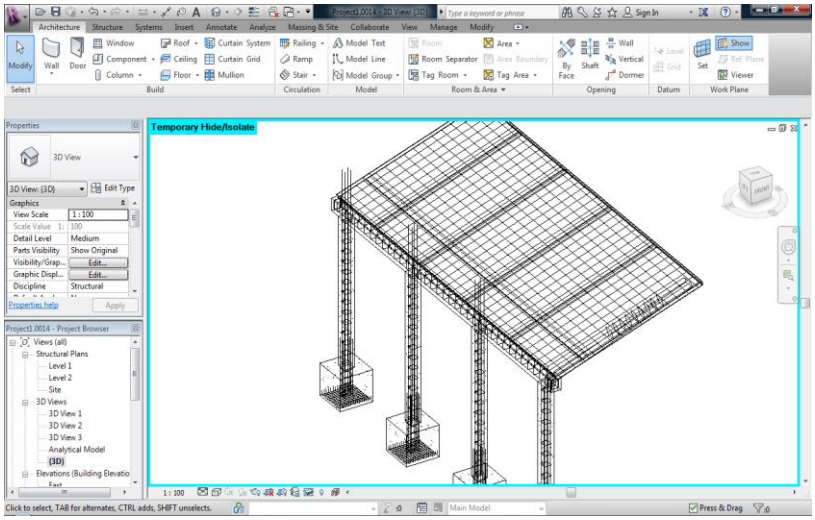

Figure 3: Engineering Reinforcement Schedule in a 3D BIM model

Figure 2 is a screen print of the petrol station modeled in Revit, from a planning and costing point of view it demonstrates BIMs virtual capabilities in order to produce documents based on limited detail. The reinforcement schedule depicted in Figure 1 has been transferred into a virtual model in Figure 3, thus enabling the construction management student the ability to investigate the intangible contingency costs associated with the magnitude of the steel content. In practice this would provide the students with a visible appreciation and enable them to analyze the risk of the construction tasks for example; formwork, scheduling and supports. It is the author's anticipation that use of software applications would increase the precision measurement of the structures components and productivity of the students. This theoretical module would be beneficial to final year students as assessment of their knowledge content at this level (formative assessment).

3.5 The Challenges of Learning Disability

Chapman (2011) highlights three key questions with regards to disability: i) are criteria for admission fair, transparent, relevant to the requirements of the program and has it been undertaken so it does not unjustifiably disadvantage or debar applicants with disabilities? ii) are applicants encouraged to disclose their impairment, within appropriate levels of confidentially and iii) does your university's admissions process allow reasonable adjustments to enable applications from disabled students to be given equal opportunity? Thompson and Pickering (2001) emphasize that there is a feeling among disabled people who may have a disability that their disability is not something of a hindrance or wish to deemphasize. They are of the opinion that society needs to remove the idea that disability is connected with lesser value. For example most people who use a wheelchair have found that the wheelchair seems to indicate to others that they are also deaf (not proven).

With regards to this example the use of virtual worlds allows for students with such disabilities to excel. The virtual world has no physical boundaries and students who attend class in a wheelchair would be as mobile as their fellow students. The possibility of linking BIM with e-learning would provide the means for such a student to attend class from their own home. Thompson and Pickering emphasize that people who have learning disabilities may lack communication skills. In relation to students who have learning disabilities such as dyslexia the communication platform provided through a BIM model is similar to Web 2.0 (Facebook etc.) as it allows for an open dialogue to be created because files are defined, structured and exchangeable. This means if a student with a disability was unable to draft a written report they can easily capture their concerned issue in a simulation movie or annotate and mark-up of an existing model. From an assessment point of view this is how the authors envision the marking criteria to be structured. The student's would be set an objective and upon completion save their work to a file (for example;.rvt for Revit software) and upload it to a designated repository.

4. FEEDBACK

4.1 BIM as an Assessment Application

In order, to achieve active learning it is challenged that shared collaboration should be promoted through facilitating groups to work together for a common goal. Early recognition by students achieving individual tasks based on collaborating can be a catalyst when evaluating and establishing a feedback cycle at the very beginning for example: encouraging students to design posters (show them previous student work) and then give prompt feedback (Keenan, 2011). The authors intention as part of an induction to the course which will follow through until completion is to illustrate completed projects. The module would be initially divided over a period of time and within each timeframe a set task would have to be achieved before proceeding. After each task the students would complete a questionnaire in order to identify the positives and negatives of their experience. As an assessment they would be required to present their task and marked on their effort. Nicol and Macfarlane-Dick (2006) recognize that there are seven principles of good practice in feedback, based on their effectiveness in strengthening student's ability to self-regulate their own performance. The seven principles are: 1) clarify what good performance is (goals, criteria, expected standards), 2) facilitate the development of self-assessment (reflection) in learning, 3) provide high-quality information to students about their learning, 4) Encourage teacher and peer dialogue around learning, 5) Encourage positive motivational beliefs and self-esteem, 6) provide

opportunities to close the gap between current and desired performance, and 7) provide information to teachers that can be used to help shape teaching.

In order, to apply feedback to practical modules involving virtual worlds the chosen assessment formats of formative, summative and ipastive would need to be consistent with digital technology used to undertake the types of assessment. For example; the errors identified in using software applications are easy to track and trace and screen prints can be applied to highlight the mistakes and returned to the students. The authors are of the opinion that the most innovative strategy to assess future generations of students cannot be governed by choosing one method but by collaborating with all three techniques such as; developing an award to identify that the attendee has completed the module and request them to fill out an online survey in order to advance the course (summative); design a project that will enable the students to use and choose the most effective BIM tools to undertake each assigned task, the course would be made-up of several tasks for example; task 1 – convert 2D drawings to a 3D model 'test', task 2 – create a program based on the model and align it with 4D BIM 'test', task 3 – quantify and cost the project using standard methods of measurement 'test' (formative), overall the students would be developing a full model over a semester based on their individual tasks (each task would require them to both learn the theory and software associated within that assignment) (ipsative). Each of the tasks should follow the guidelines set by Nicol and Macfarlane-Dick in order for the student to self-assess their performance and close the gap between current and desired performance.

4.2 Delivering 4D BIM Short Course

The concept of the short course for CIOB was to introduce the benefits of BIM to 37 attendees and to test the teaching and assessment techniques of using virtual models. The initial stage was to highlight the key attributes of BIM such as, parametric design (for example; the rules can define the minimum thickness of a wall and with object-based parametric modeling the designer can make an alternative Eastman et al. 2011) and cross-discipline co-ordination demonstrated through the virtual world simulations of the BIM model. In order, to demonstrate this concept one of the authors presented a lecture immersed in the key components of using BIM such as relationships, collaboration and integrated design and exchanging of information.

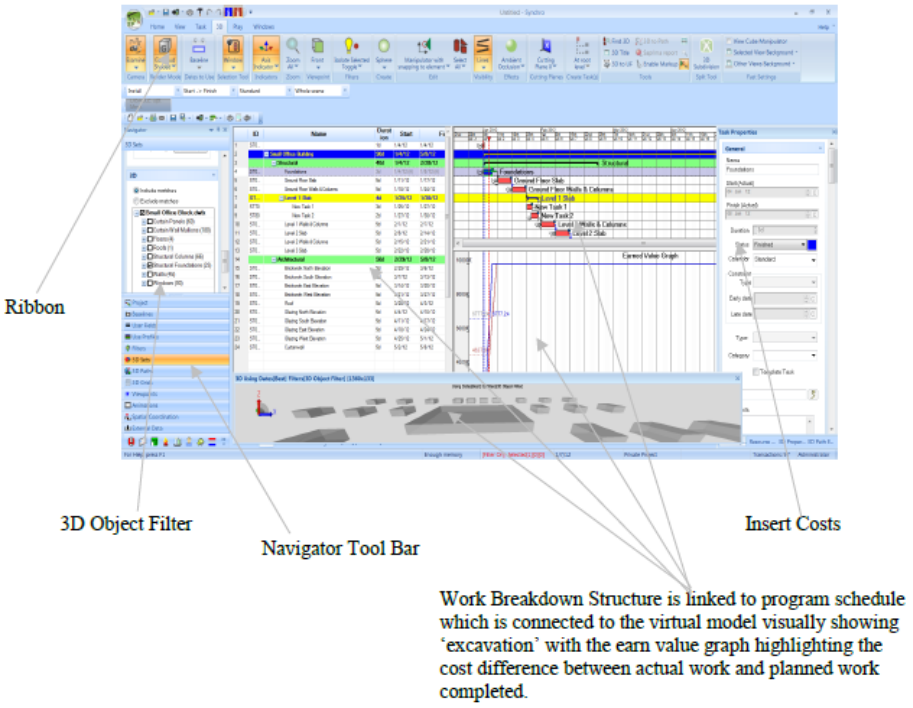

Figure 4: Financial Management through 4D BIM 'Synchro Ltd'

The following stage involved the physical "hands-on experience" meaning; showing the students how to use the main components of a 4D software application such as, importing data (importing Microsoft XML program, DWF and assigning resources), screen layout (demonstrating the various windows that will be used such as, ribbon (main menu to access the commands), 3D filters to show or hide elements, set actions, change colors and transparency and show growth simulation), linking 3D objects to the project schedule, growth simulation and reporting (highlighting how 3D subdivision can be used to convert large objects such as floors into various divisions in order to provide additional work breakdown structure tasks in a Gantt chart). These were some of the main assessment areas that were demonstrated to the construction management students in order for them to appreciate the visual and professional examination aspects of a BIM application.

The Earned Value Graph in Figure 4 was presented to show the attendees the benefits of having both a program schedule and virtual model. It also depicted the financial status of the project at that desired moment in time. This is done by analyzing the cost of work scheduled against the cost of work performed in order to define a saving or loss depending on the performance of contractor. *Summary of key findings:* As a requirement for an assessment of learning and evaluation of teaching techniques the BIM short course successfully delivered an introduction on how some of its main attributes such as collaboration and interoperability will change the attendees work environment. Through simulating BIM model to an assigned program the process provided the attendees with the self-fulfillment that their previous tasks were workable within a virtual model, which in turn would only add confidence to their decisions prior to physical construction. The feedback from one attendee stated "the course provided a very good insight into the type of technology that companies will be using when I graduate. The manner in which the technology can be used at all phases of the process was clearly communicated".

5. CONCLUSION

The incentive for this paper was based on the UK Governments 2016 BIM level 2 adaption strategy for all government buildings. As a motivation factor to keep the UK at the forefront of using the most innovative tools, modules will need to be redesigned in order to keep the construction industry on the cutting edge. The construction industry has several tools readily available within its BIM suite from a multiple of software vendors. The main focus on this paper was to identify the various types of assessment (summative, formative and ipsative) and design a feedback mechanism that would motivate students through connecting with their day-to-day learning activities while engaging in real-world (virtual) environments.

In order, for the paper to emphasize assessment, a formative assessment (promote learning) on practical work connecting features such as designing 3 and 4D BIM models based on 2D drawings was outlined. This hypothetical course would allow the students to have an active involvement in their own learning experience which consequently will enable them to assess their own qualities and improve.

On reflection of the various techniques, formative assignment has the potential to be widely used at an early adoption stage of a BIM course. The three tasks demonstrated in section 3.4, a) covert 2D drawings to a 3D model, b) create a program based on the model and align it with 4D BIM, c) quantify and cost the project using a standard method of measurement incorporates the eight principles identified in Table 1 and corresponds with Nicol and Macfarlane-Dick (2006) self-regulate performances.

The 4D Synchro Short-Course was a prototype module designed to facilitate an unique bespoke event in which the attendees learnt the theoretical propositions of BIM before engaging with a 4D BIM software package. The positive outputs from the attendees reflected the need to participate initially in a virtual practical scenario as a means to assessing sample tasks. In order to deliver a formative assessment process this paper findings have shown that BIM is a powerful collaboration tool that adds value through virtualization and self-learning mechanisms.

ACKNOWLEDGMENTS

The authors would like to say thank you to Dr Philip Long (Lecturer at Anglia Ruskin University – Faculty of Health, Social Care & Education), Mr. Michael Murphy (BAM - Ireland) and Mr. Deke Smith (The National Institute of Building Sciences).

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