www.itcon.org - Journal of Information Technology in Construction - ISSN 1874-4753

BUILDING INFORMATION MODELLING (BIM) EDUCATIONAL FRAMEWORK FOR QUANTITY SURVEYING STUDENTS: THE MALAYSIAN PERSPECTIVE

SUBMITTED: November 2015
REVISED: April 2016
PUBLISHED: July 2016 at http://www.itcon.org/2016/9
EDITOR: Issa R.

Kherun N. Ali, Dr.,
Department of Quantity Surveying, Faculty of Built Environment, Universiti Teknologi Malaysia;
b-kherun@utm.my

Nur E. Mustaffa, Assoc. Prof.,
Department of Quantity Surveying, Faculty of Built Environment, Universiti Teknologi Malaysia;
b-nuremma@utm.my

Quek J. Keat, Sr.,
Royal Institution of Surveyors Malaysia (RISM);
jkquek@kpkqs.com

Wallace I. Enegbuma, Dr.,
Department of Quantity Surveying, Faculty of Built Environment, Universiti Teknologi Malaysia;
wenegbuma2@live.utm.my

SUMMARY: *For the past few years, the wave of Building Information Modelling (BIM) has been hitting the shores of Malaysian construction industry. The unprecedented change it brings to the design responsibilities of construction professionals in Malaysia has led to a pre-emptive strategic focus for Quantity Surveying (QS) profession. The QS profession adheres to the 5th dimension of BIM, which invariably translates to the context of costing, offering the capability to generate quantity take-off, counts and measurement directly from a model. BIM digitalized data lead to accurate automated estimation which reduces variability in cost estimation. From the academic point of view, requirements to meet this paradigm shift to BIM requires an enhancement to the existing set of skills and knowledge available in Malaysian institutions of higher learning. The promotion of BIM educational framework for the QS graduates have been professional body led. This is carried out by the Royal Institution of Surveyors Malaysia (RISM) which has been actively involved in establishing the educational framework which in turn has been referred to by the higher institutions that offers quantity surveying program. This paper describes the educational framework for the QS in the context of BIM implementation that charts a route on how knowledge on BIM principles and its application can be imparted to the whole-life inter-disciplinary design and construction with prime focus on the QS scope of work. The primary aim of the framework lies in equipping QS graduates with the necessary skills in project delivery through the use of BIM by focusing on four spheres of attainment level and two different level of knowledge acquisition.*

KEYWORDS: *Building Information Modelling, Education, Framework, Quantity Surveying, Malaysia*.

REFERENCE: *Kherun N. Ali, Nur E. Mustaffa, Quek J. Keat, Wallace I. Enegbuma (2016). Building information modelling (BIM) educational framework for quantity surveying students: The Malaysian perspective. Journal of Information Technology in Construction (ITcon), Special issue: 9th AiC BIM Academic Symposium & Job Task Analysis Review Conference, Vol. 21, pg. 140-151, http://www.itcon.org/2016/9*

1. INTRODUCTION

The construction industry development board (CIDB) BIM roadmap (2014-2020) projects the actualization of about 300 to 600 skilled BIM graduate users per year from the schools of engineering and environment in various institutes of higher learning in Malaysia (CIDB, 2014). The McGraw Hill report (2009) opined that BIM inclusion into education pedagogy is crucial in preparing skilled graduates for employment in the industry. Meanwhile, the previous McGraw Hill report (2008) posits the inadequacy of strategy and capabilities of institutions of higher learning to introduce BIM which provides a wide hurdle to the BIM adoption. The overwhelming state of development of collaboration in construction utilizing BIM tools and processes raises concern on the readiness of institutions of higher learning (Becerik-Gerber et al., 2011; Allen Consulting Group, 2010; Forgues et al. 2011; Macdonald, 2012). Table 1 highlights the areas of QS involvement during the construction lifecycle of a project both pre-and-post construction. BIM has the potential to automate processes which are time consuming in the quantification of cost (Hannon, 2007; Mitchell, 2012; Nagalingam et al., 2013; Thurairajah and Goucher, 2013; Fung et al., 2014). It provides students with greater insights to construction divisions, clash and visual details, increased level of communication, increased speed and accuracy in quantity take off (Azhar et al., 2010; Taylor et al., 2008; Gier, 2008). The Royal Institute of Chartered Surveyors (RICS) report found that BIM significantly improves efficiency and accuracy which therefore improves relevance of the profession (Withers, 2014).

TABLE 1: Stages of QS involvement in construction (Olatunji et al., 2010; Fung et al., 2014)

Pre-Construction Stage	Post-Construction Stage
Preliminary estimates and feasibility studies	General contractual advice
Cost plans and schedules	Assessing interim payments
Bills of quantities preparation	Evaluating variation
Procurement and tendering procedures	Preparing finance statements
Evaluation of tenders	Settling final account
	Alternative dispute resolution

These advantages of BIM in education however faces challenges in implementation which among others include factors such as absence of BIM in curriculum, inadequate time and resource deployment to develop curriculum, lack of available BIM reference materials, inadequate skills on software, reluctance by students and faculty on the need to transform in line with advancement in technology-based curriculum (Sabongi and Arch, 2009; Clevenger et al. 2010; Enegbuma et al., 2010; Sylvester and Dietrich, 2010) and limited occurrence of research into BIM potentials in the QS profession (Mitchell, 2012; Perera et al., 2011; Fung et al., 2014). QS BIM research in Malaysia found through an interview survey that 11 capabilities of BIM were in consonance with the professionals' perception. This is shown in Table 2 below.

TABLE 2: QS BIM Capabilities in Malaysia (Fung et al., 2014)

1	Cost appraisal can be prepared quickly at feasibility stage
2	Preliminary cost plan can be prepared by extracting quantities from model
3	Easily update cost plan more details as design developed
4	Easily generate accurate cost estimates for various design alternatives
5	Design changes reflected consistently in all drawing views
6	Cost implication of design changes can be generated easily
7	Clash detection reduces design errors and cost estimates revisions
8	Cost checking performs quickly to ensure all items are captured
9	Improve visualization for better understanding of design
10	Automatically quantification for BQ preparation
11	Intelligent information management data can be stored in centrally

BIM was first mentioned in Malaysia during a two-day infrastructure and construction Asia Building Information Modelling and Sustainable Architecture Conference in 2009 (Ismail, 2014). This conference prompted the paradigm shift to BIM industry wide. Awareness through conference and seminars began increasing the pace of BIM adoption in the industry (Ismail, 2014). Previous research highlighted the inadequacies in aspects of interoperability, standard forms of contract relating to BIM, education pedagogy of BIM in institutions of higher learning and with the high cost of training and software purchase (Enegbuma and

Ali, 2011). The BIM adoption model for Malaysia proposed by Enegbuma and Ali (2012) supported the interrelations between soft issues (People, Process and Technology) with strategic IT implementation mediated by collaborative processes to improve BIM adoption. Business process re-engineering had the highest effect on BIM adoption (Enegbuma et al., 2014a,b). The process changed in the Malaysian construction industry lead to the 2010 National Cancer Institute (NCI) pilot project utilizing BIM (Ismail, 2014). The Construction Industry Development Board (CIDB) in 2011 initiated the National BIM steering committee. Part of the committee's task was to monitor education and awareness in academia (Ismail, 2014). Subsequently, the Malaysian Chapter of the BuildingSMART international was launched. The Malaysian BIM roadmap workshop involving representatives from Persatuan Arkitek Malaysia (PAM), Board of Engineers Malaysia (BEM), Royal Institution of Surveyors Malaysia (RISM), Perumahan Rakyat 1 Malaysia (PR1MA), Sime Darby Properties, Economic Planning Unit (EPU), University Malaysia Pahang (UMP) and private developers listed Academia as the number two motivators to BIM implementation. The third thrust of the Malaysian BIM roadmap 2014-2020 also hinged on education and awareness. Thus, the aim of this paper is to formulate and validate a BIM framework for quantity surveying students in Malaysia. The following sections will highlight the methodology, examine global BIM in education and present the proposed Malaysian BIM education framework.

2. BIM AND QUANTITY TAKE-OFF

Quantity take-off is envisaged to enable precise and accurate estimation (Eastman et al., 2011) however, the reliance on extracted metadata export from the BIM model will invariably affect the accuracy (Zhiliang et al., 2011). BIM transforms traditional QS practice and offers solutions to a varying range of challenges in traditional quantity estimation but is unable to claim an overriding solution in all instances (Olatunji and Sher, 2014). Estimators still face the challenges of manipulating data extracted from the BIM model to translate into cost estimates. Such models are vital to enhance client and project professionals understanding of the project at hand (Olatunji and Sher, 2014). BIM enabled estimation was classified by Olatunji and Sher (2014) as:

- **IFC Export Approach:** This technique requires the exportation of BIM data to estimate software which are structured to suit Industry Foundation Classes (IFC). The data is then converted to spreadsheet and readily edited by estimators (Olatunji and Sher, 2014). Algorithms are used to extract and filter IFC data to conform to project specifications and bill of quantities. However, IFC translators are ill-equipped to handle unstandardized or unlinked components of models (Ma et al., 2013; Zhiliang et al., 2011; Ji et al., 2011).
- **Model 'as-is' Costing Approach:** This technique requires the direct building of cost data into the model (Yum et al., 2008; Olatunji and Sher, 2014). Hence, every component is costs separately and prevented from being edited in any application. Cash flow and timing are easily estimated. Issues arise in data reliability when dealing with components merged from a designer's perspective as against those of a quantity surveyor (Olatunji et al., 2010; Olatunji and Sher, 2014).
- **Model Moderation Cost Approach:** This technique requires the merging of data from models created on different applications and is not commonly used by estimators (Olatunji, 2012; Tiwari et al., 2009; Olatunji and Sher, 2014). The limiting factor of this approach arises from the inadequate authorization setting which prevent editing of merged data from different sources. Additionally, clients are exposed to exploitation when unclear data are estimated above price range by a project team member (Olatunji and Sher, 2014).
- **Process Simulation Costing Approach:** This technique is based on simulation of the construction process from inception to project conclusion. The limiting factor lies in the inability of the simulation to reflect the true nature of resources and delimit them from addition as contract documents (Olatunji and Sher, 2014).

3. QUANTITY SURVEYING COMPETENCY

Competency is defined as an all-encompassing expectation of a professional in a work place where application of skills and knowledge to tackle new situations and job scope is required (Golob, 2002; Mohd Derus et al., 2009). These competencies in the long-run lead to competitive advantage (Deist and Winterton, 2005). Stewart (2012) recommends that the QS profession align with present BIM drive, have more research in quantity take-off with BIM and produce a new standard, keeping in mind the compatibility of the software. The collaboration principles of BIM remains incomplete without the input of cost professionals in the BIM model at 4D and 5D (McCuen, 2008; Stewart, 2012). Software companies are most likely to produce measurement software which suit BIM quantity extraction in large market as opposed to smaller diverse markets.

Standard measurement difference such as Ireland Agreed Rules of Measurement (ARM), UK New Rules of Measurement (NRM), Malaysian Standard Method of Measurement of Building Works (SMM) and others, create conflicting software needs which require adjustments for each market (Olatunji et al., 2010; Stewart, 2012; Yusuf et al., 2013). The UK New Rules of Measurement (NRM) is recently used for various stages of construction namely:

- NRM 1: Order of cost estimating and cost planning for capital building works
- NRM 2: Detailed measurement for building works
- NRM 3: Order of cost estimating and cost planning for building maintenance works

NRM1 caters for the quantification of building works used in preparing cost estimates and cost plans, NRM 2 guides the detailed measurement and description of building works used during a tender pricing and NRM 3 extends to guide quantification and description of maintenance works used in preparing initial order of cost estimates during the preparation stages, cost plans during the design development and preconstruction stages, and detailed, asset-specific cost plans during the pre-construction phases (Cartilidge, 2011; RICS, 2012; Wu et al., 2014). This new process of measurement provides a consistent approach for cost management and improves understanding of measurement rules by various collaborating professionals (Lee et al., 2011; RICS, 2012). Wu et al., (2014) opined that for measurement using BIM, quantities should be exported to link BIM estimating with design tool and use specialised BIM measurement tool. However, issues of substandard quality of BIM models, inconsistent level of design information, data exchange and inconsistent formats used for estimating still exits.

Current research in Malaysia recomends the use of SMM for preparing BoQ for M&E services as opposed to schedule of prices to reduces risk of price uncertainty and improved client value. Hence, estimation using BIM requires the filtration of BIM data to conform to SMM (Yusuf et al., 2013). In terms of soft skills demanded by employers of quantity surveyors, Shafie et al. (2014) found that having high level of critical thinking, problem solving and decision-making abilities ranked highest for employer skill demanded. These soft skills are inline with that of the Ministry of Higher Education (MOHE) 2006 (see below):

- Communication skills (CS)
- Critical thinking and problem-solving skills (CTPS)
- Teamwork skills (TS)
- Lifelong learning and information management skills (LL)
- Entrepreneurship skills (ES)
- Ethics and professional moral (EM) and;
- Leadership skills (LS)

Mohd-Derus et al. (2009) posited that organizational environment, job demand, and individual competencies define competency of a QS. Other professional practice competency studies are shown in Table 3.

TABLE 3: Previous Studies in QS Practice Competency

Ethical concept and ethical behaviour	Ho and Ng, 2003; Fan et al., 2001a, 2001b; Bowen et al., 2007
Knowledge management	Woods, 2007; Bakri and Khaderi, 2007; Azam and Aziz, 2006
Strategic planning	Hassan et al., 2007
Profession branding	Preece and Moodley, 2007
Adjudication	Munaaim and Loh, 2007
Venturing into non-construction services	Zakaria et al., 2007
Education	Sher et al., 2007
Continuous professional development	Ariffin and Torrance, 2008
Leadership	Fellows et al., 2003
ICT	Fogg, 2007; Aouad et al., 2007
Behavioural competencies	Nkado and Meyer, 2001; Karim and Mohd-Derus, 2007
Technical competencies	Nkado and Meyer, 2001

Stanley and Thurnell (2014) suggest that incompetency and lack of protocols relevant to foster effective collaboration within the BIM team forms a limiting factor to BIM use. Gardner et al. (2014) found similar barriers in BIM competency among graduates in South Australia. This competency trait is a close parallel to the competency highlighted by Royal Institution of Chartered Surveyors (RICS) BIM manager certification which measures BIM initiation, processes and collaboration and integration including optional competencies of commercial and technical abilities (White, 2013). Lewis et al. (2015) further found that BIM training improve students' confidence and perception of utilizing BIM in energy simulation of buildings for improving sustainable designs and construction related courses. Nath et al. (2015) found that among Singapore construction precasters, workflow comparison of current and future BIM utilization revealed an increase in overall productivity improvement of approximately 36% for processing time and 38% for total time. Accordingly, HDB seeks to leverage the BIM capabilities to improve the construction productivity through increased support for standardization of precast elements which eventually leads to error-free generation of shop drawings. Wood et al. (2014) developed a framework to address the need to comprehend the level of development (LOD) of construction professionals in the construction industry. The framework extracts materials information from BIM and subsequently provided an algorithm to fuzzy match BIM objects with cost data for quantity measurements. Morlhon et al. (2014) developed a critical success factor model which integrates capability maturity model (CMM) and critical success factors (CSFs) focusing on BIM impact on project management. The CSFs include business process re-engineering, standardization, external stakeholders influence, education to information management, technical education and systems selection process. A summary of competencies for QS students utilizing BIM is shown in Table 4.

TABLE 4: Summary of BIM Competencies for Quantity Surveying Students

Competency	Skill Set	Author
Quantity Take-off	Ability to utilize BIM for quantity take-off	Monteiro and Martins (2013)
Energy Modelling (EM)	Building element based energy simulation	Lewis et al. (2015)
Precast Productivity	Shop drawing development and quantity take off	Nath et al. (2015)
Level of Development (LOD)	Structural design quantity take-off	Wood et al. (2014)
Project Management	Project monitoring	Morlhon et al. (2014)
Bill of Quantity	Developing BoQ for M&E services	Yusuf et al., 2013
Collaboration	Adapting to collaborative work environments	Gardner et al. (2014)

4. EXISTING FRAMEWORKS ON BIM EDUCATION

Macdonald and Mills (2011) postulate the need to establish BIM education framework to support adoption of collaborative design and BIM education by Architecture, Engineering and Construction (AEC) schools. Additionally, Macdonald (2012) developed the Illustration, Manipulation, Application and Collaboration (IMAC) framework to help teachers benchmark their curriculum to improve collaborative design education among students of the architecture, engineering and construction (AEC) disciplines. The framework synthesized Bloom et al. (1956) learning taxonomy which classify learning into cognitive, affective and psychomotor and Krathwohl et al. (1964) which extended the classification to include changes in interest, attitude and values. The framework aims to redeveloping current course to accommodate BIM competences for different disciplines. The framework under Illustration, Manipulation, Application and Collaboration target disciplines into management, specialism, IT, building technology and environment respectively. The disciplines are encouraged through partnership with University of Technology Sydney, University of South Australia and University of Newcastle. The full IMAC education model is illustrated in Figure 1.

Illustration (Knowledge/Comprehension and Receiving/Responding)
Separate disciplines and illustration of key concepts

Manipulation Stage (Comprehension/Application and Responding/Valuing)
Students begin to manipulate BIM model in relations to their discipline

Application Stage (Application/Analysis and Valuing/Organizing)
Applying knowledge to solve discipline related problems and learn to collaborate

Collaboration Stage (Synthesis/Evaluation and Characterizing)
Working on a joint project, improve group and teamwork

FIG. 1: IMAC BIM Education Framework Australia (Macdonald, 2012)

The change to BIM by the UK government in the UK BIM Report and Government Construction Strategy (GCS) lead the UK BIM Academic Forum (BAF) to discuss strategic improvements for academia. BAF highlighted the need to improve the skills of staffs to support the delivery of the desired learning outcomes on BIM; industry to push for student employability with BIM competence; framework for learning and; the need to keep pace with the development of BIM. The learning outcomes shown in Figure 2 are divided accordingly, it begins at level 4 (year one of undergraduate study) where students will be introduced to context and background of the industry professions and how collaboration within the BIM technology works. Level 5 (year 2) entails developing the knowledge and understanding of BIM as a business driver for collaborative works which affects the whole life cycle cost of projects. Level 6 (year 3 and potentially after a year out in industry) focuses on building competence and knowledge around people, systems and process (HEA, 2013).

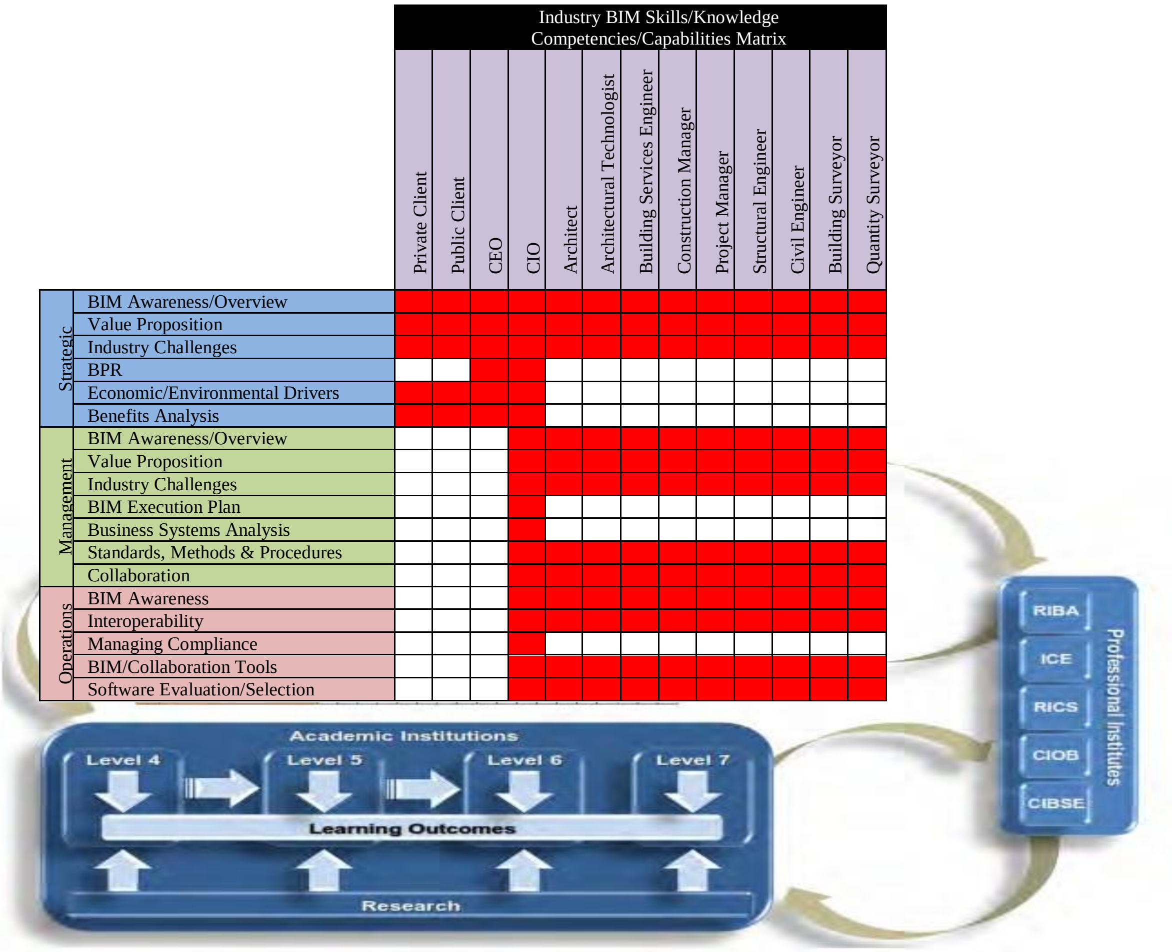

FIG 2: Initial UK BIM Learning Outcome Framework (HEA, 2013)

Clevenger et al. (2010) reported a positive feedback from students of construction management education in a pilot implementation of BIM in education by Colorado State University (CSU). CSU deployed BIM framework in two stages with a strategy to integrate BIM into construction management curriculum. The first, was the establishment of an introductory BIM software course and secondly, to develop stand-alone teaching modules for integration into a variety of core courses including, but not limited to structures, mechanical, electrical and plumbing (MEP) coordination, sustainable design and construction, pre-construction, cost estimating, scheduling, contracts, and material and methods. The framework expressed the need to inculcate core construction concepts into the teaching of BIM to showcase leading industry best-practices. It is a different variant from popular software tutorials. Barison and Santos (2010a) found that BIM implementation follow 3 processes namely; single course module (Hu, 2007; Nielsen et al., 2009), interdisciplinary (Hedges et al., 2008; Plume and Mitchell, 2007) and distance collaboration (Hedges et al., 2008; Dilg, 2008). The predominant approach to the introduction of BIM is in design studio of four different course in the curriculum namely;

visualization, quantification, planning and scheduling and management (Barison and Santos, 2010a). The lack of integration among different course curriculum presents a great challenge to implementing BIM pedagogy. Kymmell (2008) and Barison and Santos (2010a) recommend the need to focus on individual skills on BIM model in first year, expansion to teamwork and complex collaboration in the second year and further expansion to real life projects in collaboration with construction companies in the third year.

5. METHODOLOGY

The findings of this paper were actualised through the processes of critical literature review, interview and focus group discussion. The breakdown of the intended end users in the Malaysian educational system consisted of 20 public universities, 33 private universities and university colleges, 22 polytechnics, 37 community colleges and 500 private colleges (MOHE, 2014). The first step of the study involved the gathering of more insight into educational research and framework across the globe. An extensive literature review was carried out to derive the objectives, medium and learning outcome to be adapted in the BIM education framework for quantity surveying students (Creswell, 2012). The second step was an extension of the literature findings through an open-ended interview of 15 construction professionals adept with knowledge on BIM. The professionals were selected based on years of experience in the construction industry, preferably, an experience of 10 years and more. The construction professionals were registered members with the Board of Quantity Surveying Malaysia (BQSM) (Creswell, 2012; Ajagbe et al., 2015). The third step entailed fine-tuning the initial framework to include validation feedback from a focus group discussion at the international workshop on BIM education and training content development organised by the Royal Institution of Surveyors Malaysia (RISM). The participants of the focus group discussion numbered 30 (thirty) in total. They were selected based on the years of experience (10 years and more), their quantity surveying background and knowledge on BIM cost estimation. The respondents were all registered members of the BQSM. The focus group discussion was divided into five groups. The groups were required to discuss BIM education and training namely; (1) general knowledge on BIM in Malaysia, the region and the world; (2) measurement rules for building and MEP; (3) how RISM can do to facilitate changes; (4) BIM management and contract and; (5) modalities to steer and request information from designers to effectively extract quantities (Haron, 2013). The fourth and final step was the framework assessment by QS Accreditation Council (QSAC), BQSM. The QSAC was to assess the framework for its relevance to improving the skills of QS graduates. The framework was to be considered as part of the components in the accreditation exercise. The accepted framework was subsequently presented and discussed in a dialogue between BQSM and representatives of the public and private Institutions of Higher Learning (IHL) that have quantity surveying programs both at Diploma and Degree level. The dialogue was to get feedbacks and comments to further improve the framework. The amended framework was subsequently endorsed by BQSM. The decision to accept the framework mandates public and private institution of higher learning that offer QS programs to insert BIM in their syllabus.

6. FRAMEWORK AND DISCUSSION

The analysis of BIM education framework lead to the division of QS BIM framework into four (4) objectives namely; visualization, quantification, planning and scheduling and management. The subsequent learning outcomes were currently limited to two concurrent phases of the Diploma and Degree levels. In order to achieve in-depth knowledge on visualization in BIM models, three courses namely Draughtsmanship, Construction Technology and Construction Services were identified as means to enhance visualization in BIM. Draughtsmanship courses will be further enhanced to include the use of BIM software as a basic tool for design. Construction Technology will include BIM and is envisaged to improve the students' knowledge and skills of construction building codes, construction documents, mechanical systems and construction safety. The developed framework is outlined in Table 5.

Quantification will comprise of Measurement and Cost Estimating. These components will improve the level of quantity surveying students understanding of BIM for effective measurement. These skills will improve the employability of the graduates and demand for the profession within the growing BIM industry. In Planning and Scheduling, Cost Planning and Cost Analysis courses will improve the QS students' skills in line with BIM compliant software. Finally, Management will incorporate improved Project Management, Professional Practice and Contract courses to include legal dimension, BIM competence expectancy in the job market and lifecycle BIM management of a project.

TABLE 5: BIM Education Framework for Quantity Surveying Students in Malaysia

			Diploma	Degree
AIM	**OBJECT**	**MEDIUM**	**OUTCOME**	**OUTCOME**
To equip QS graduates with appropriate skills in project delivery through the use of Building Information Modelling	Visualisation	Draughtsmanship	To be able to appreciate 2D design and basic 3D models	To be able to appreciate 2D design and basic 3D models
		Construction Technology		
		Construction Services		
	Quantification	Measurement	To be able to apply the quantity take-off software and spreadsheets software	To be able to apply the quantity take-off software and spreadsheets software
		Cost Estimating		
	Planning and Scheduling	Cost Planning & Scheduling	To be able to appreciate the fundamental principle of cost planning and cost analysis through the application of appropriate software	To be able to understand the fundamental principle of cost planning, scheduling and cost analysis through the application of appropriate software
		Cost Analysis	To be able to appreciate the economics of construction project using digital data through the application of appropriate software	To be able to evaluate the economics of construction project using digital data through the application of appropriate software To be able to integrate 4D (scheduling) and 5D (QS BIM) into their tasks
	Management	Contract	To be able to appreciate the legal implications of the integrated project delivery system	To be able to assess the legal implications of the integrated project delivery system
		Professional Practice	To be able to appreciate the procedural aspects of the integrated project delivery system	To be able to assess the procedural aspects of the integrated project delivery system
		Project Management	To be able to appreciate the complexity of working in interdisciplinary teams and managing collaborative design and production To be able to appreciate a construction project through visualisation of construction process	To be able to assess the complexity of working in interdisciplinary teams and managing collaborative design and production To be able to manage a construction project through visualisation of construction process

The desired learning outcomes for the quantity surveying education framework is targeted to ensure that at the diploma level, quantity surveying students are able to master visualization and quantification utilizing BIM as a foundation to future degree studies. At the degree level, the foundation is extended to include evaluation and integration of BIM in cost planning and scheduling task. Similarly, legal liabilities and effective integrated project delivery are taught to differentiate the two classes of learning outcomes. To achieve the aforementioned learning outcome, the framework took into account the need to upgrade quantity surveying student's skills in Microsoft Excel from the basic knowledge to a more advanced use of the software. The task of quantification and automatic take-off from BIM models is improved through upgrading the skills in various BIM interoperable software. The learning approach will involve hands-on lectures and will include BIM related courses. The difference in the level of advanced learning between the diploma and degree also arise from the course duration which ranges from 2.5-3 years for diploma and 3-4 years for degree depending on the institution and student performance.

The framework for QS students in Table 5 was validated through the focus group discussion. The feedbacks emphasized the need for changes to physical conditions of institutions of higher learning covering reference materials, training of staffs, hardware and software including the establishment of a planning, review and monitoring panel consisting of three (3) members adept in BIM/IT knowledge. On visualization, the emphasis was placed on students' understanding of 2D/3D visual design tools and improving the understanding of Level of Details (LOD) in BIM models from 100-500LOD. In Quantification, the emphasis was on software choice for quantity take-off, effective use of standard method of measurement (SMM), comprehension of quantity cost within a model and updates to design changes. On Planning and Scheduling, the focus was similar to those mentioned in the previous quantification objective with variations in information use directed to sustainable construction, cost effectiveness, life cycle costing and scheduling. Finally, in Management, the emphasis was on students' comprehension of the 7th dimension of BIM models, the legal implication surrounding model ownership, liability of various professionals in BIM modelling and regular updates of BIM roles and best practices.

7. CONCLUSION

This paper developed a framework to equip QS students with the necessary knowledge and practical skills to meet the industry demand for BIM competent graduates. The framework involved four dimensions of visualization, quantification, planning and scheduling and management. These dimensions were further broken down into 10 mediums targeting various learning outcome for both Diploma and Degree QS program in Malaysian Institutions of Higher Learning (IHL). The framework was presented, assessed and accepted by the QS Accreditation Council (QSAC). The framework was also presented at a dialogue session involving the Board of Quantity Surveying Malaysia (BQSM) and members from the public and private IHLs. The decision to accept the framework mandates public and private institutions that offer QS programs to include BIM in their syllabus in accordance to the framework. The framework emphasized the importance of improving the skills of QS graduates from the diploma and degree programmes. Nevertheless, the success of the QS BIM framework is very much dependent on the commitment and willingness to overcome the resistance to change by educators of higher institutions of learning as experienced in previous BIM education frameworks (Clevenger et al., 2010; Barison and Santos, 2010a; Macdonald, 2012; HEA, 2013). These efforts are geared towards supporting the industry and government initiatives to BIM implementation in Malaysia. This change will set the standard for the Malaysian institutions of higher learning to be at par with QS graduates across the globe. The framework also recommends an increase in the awareness of BIM in institutions of higher learning, organization of BIM design competitions and initiating BIM software proficiency training. Future research could be directed towards curriculum development, assessing perception of students and lecturers and extension of framework for higher graduate courses.

8. ACKNOWLEDGMENT

The authors acknowledge the efforts of the BIM technical committee, the Royal Institution of Surveyors Malaysia to make BIM implementation a reality.

9. REFERENCES

Ajagbe, A. M., Sholanke, A. B., Isiavwe, D. T. and Oke, A. O. (2015). Qualitative Inquiry for social sciences. International Conference on African Development Issues (CU-ICADI) 2015: Social and Economic Models for Development Track, African Leadership Development Centre, Covenant University Canaanland, Ota Ogun State, Nigeria.

Azhar, S., Sattineni, A. and Hein, M. (2010). BIM Undergraduate Capstone Thesis: Student Perceptions and Lessons Learned. Retrieved from: http://ascpro.ascweb.org/chair/paper/CEUE200002010.pdf.

Barison, M. B. and Santos, E.T. (2010a). BIM Teaching Strategies: An Overview of Current Approaches, Computing in Civil and Building Engineering, Proceedings of the ICCCBE2010, Nottingham, UK: 577.

Barison, M. B. and Santos, E. T. (2010b). Review and Analysis of Current Strategies for Planning a BIM Curriculum. Proceedings of the CIB W78 2010: 27th International Conference. Blacksburg, VA: Virginia Tech: 1-10.

BIMTG (2012). Initial BIM Learning Outcomes Framework v1.0. Retrieved from: http://www.bimtaskgroup.org/wp-content/uploads/2013/04/Initial-BIM-Learning-Outcomes- Framework-v1-0.pdf.

Bloom, B. S., Englehart, M. D., Furst, E. J., Hill, W. H., Krathwohl, D. R. (1956). The Taxonomy of Educational Objectives, The Classification of Educational Goals, Handbook I: Cognitive Domain, David McKay Company, New York, N.Y.

Cartlidge, D. (2011). New Aspects of Quantity Surveying Practice. Oxon: Spon Press.

CIDB (2014). Building Information Modelling (BIM) Roadmap for Malaysia's Construction Industry (2014-2020). Construction Industry Development Board Workshop Report (Series 2).

Clevenger, C., Ozbek, M., Glick, S. and Porter, D. (2010). Integrating BIM into Construction Management Education. EcoBuild Conference Proceedings, EcoBuild 2010 BIM Academic Forum, Washington D.C.

Creswell, J. W. (2012). Educational Research: Planning, Conducting and Evaluating Quantitative and Qualitative Research 4th Ed. Pearson Education Inc. Boston.

Dilg, B. C. (2008). The Migration from AutoCAD to BIM using Revit at Ferris State University. Building Smart Alliance National Conference Engineering and Construction, Washington D.C, USA.

Enegbuma, W. I., Yuen, K. W. and Ali, K. N. (2010). ICT Competence amongst Quantity Surveying Students in Malaysia. 3rd International Graduate Conference on Engineering, Science, and Humanities Proceedings (IGCESH2010), Johor, Malaysia.

Enegbuma, W. I. and Ali, K. N. (2011). A Preliminary Study on BIM Implementation in Malaysia. Proceedings of the 3rd International Post Graduate Conference in Engineering (IPCIE2011) edited by Liu, S. Z., Javed, A. A., Ni, F. D. and Shen, A. W. 2: 399-407. 11th – 12th July, Hong Kong.

Enegbuma, W. I. and Ali, K. N. (2012). Theoretical Framework for Building Information Modelling Penetration in Malaysian Construction Industry. Proceedings of the Management in Construction Research Association (MiCRA) Postgraduate Conference, 5th December, Kuala Lumpur, Malaysia.

Enegbuma, W. I., Aliagha, U. G. and Ali, K. N. (2014a). Preliminary Building Information Modelling Adoption Model in Malaysia: A Strategic Information Technology Perspective. Construction Innovation, 14(4): 408-432.

Enegbuma, W. I., Aliagha, U. G. and Ali, K.N. (2014b). Measurement of Theoretical Relationship in Building Information Modelling Adoption in Malaysia. Proceeding of the 31st International Symposium on Automation and Robotics in Construction and Mining (ISARC). Sydney: 1000-1008.

Fung, W. P., Salleh, H. and Rahim, F. A. M. (2014). Capability of Building Information Modeling Application in Quantity Surveying Practice. Journal of Surveying, Construction and Property (JSCP), 5(1): 1-13.

Gier, D. (2008). What Impact Does Using building Information Modeling Have on Teaching Estimating to Construction Management Students?. Retrieved from: http://ascpro0.ascweb.org/archives/cd/2008/paper/CEUE179002008.pdf

Hannon, J. J. (2007). Estimators' Functional Role Change with BIM, AACE International Transactions. 1-8.

Haron, A. T. (2013). Organisational Readiness to Implement Building Information Modelling. A Framework for Design Consultants in Malaysia. PhD Thesis School of the Built Environment Faculty of Business, Law and the Built Environment. University of Salford Manchester, Salford.

HEA. (2013). Embedding Building Information Modelling (BIM) within the taught Curriculum. Higher Education Academy: BIM Academic Forum.

Hedges, K. E. et al. (2008). Socially Responsible Collaborative Models for Green Building Design. In 2008 AIA RFP Research Program Grant, Laramie USA.

Hu, W. (2007). Implementing a Simultaneous Construction Model to Educate Undergraduates in Collaboration. Annual Conference of American Society for Engineering Education, Honolulu, Hawaii.

Ismail, M. H. (2014). Building Information Modelling: A Paradigm Shift in Malaysian Construction Industry. BinaTECH, 2:34-37.

Krathwohl, D. R., Bloom, B. S., Masia, B. B. (1964). The Taxonomy of Educational Objectives: The Classification of Educational Goals, Handbook II: Affective Domain, David McKay Company, New York, N.Y.

Kymmell, W. (2008). Building Information Modelling: Planning and Managing Construction Projects with 4D CAD and Simulations, New York: McGraw Hill.

Lee, S., Trench, W., & Willis, A. (2011). Willis's Elements of Quantity Surveying. Chichester: John Wiley & Sons Ltd.

Macdonald, J. A. (2012). A Framework for Collaborative BIM Education across the AEC Disciplines. 37th Annual Conference of the Australasian Universities Building Educators Association (AUBEA), The University of New South Wales, Australia.

Macdonald, J. A. and Mills, J. E. (2011). The Potential of BIM to Facilitate Collaborative AEC Education. American Society for Engineering Education Annual Conference, Vancouver, Canada, Proceedings of the 118th ASEE Annual Conference, American Society of Engineering Education, Vancouver, Canada

McGraw Hill Construction SmartMarket Report. (2009). The Business Value of BIM: Getting Building Information Modeling to the Bottom Line.

McGraw Hill Construction SmartMarket Report (2008). Building Information Modeling: Trans-forming design and construction to achieve greater industry productivity.

MOHE. (2014). Statistics of Institutions of Higher Learning. Retrieved from: http://www.moe.gov.my/en/home.

Mitchell, D. (2012). 5D BIM: Creating Cost Certainty and Better Buildings. Paper Presented at the 2012 RICS Cobra, Las Vegas, Nevada USA.

Nagalingam, G., Jayasena, H. S. and Ranadewa, K. (2013). Building Information Modelling and Future Quantity Surveyor's Practice in Sri Lankan Construction Industry. Paper Presented at The Second World Construction Symposium 2013: Socio-Economic Sustainability in Construction, 14-15 June 2013, Colombo, Sri Lanka.

Nielson, D., Fleming, M. and Kumarasuriya, A. (2009). An Innovative Learning Model for Teaching Architectural Technology using Building Information Modelling: A Queensland University of Technology Perspective. EDULearn09 International Conference on Educational and New Learning Technologies, Barcelona, Spain.

Olatunji, O. A., Sher, W. and Gu, N. (2010). Building Information Modeling and Quantity Surveying Practice. Emirates Journal for Engineering Research, 15 (1), 67-70.

Perera, S., Udeaja, C., Zhou, L., Rodrigo, A. and Park, R. (2012). Mapping the E-business Profile and Trends in Cost Management in the UK Construction Industry. Retrieved from http://innovationinaec2012.pcc.usp.br/PROCEEDINGS/88%20MAPPING%20THE%20EBUSINESS%20PROFILE%20AND%20TRENDS%20IN%20COST%20MANAGEMENT%20IN%20THE%20UK%20CONSTRUCTION%20INDUSTRY.pdf

Plume, J. and Mitchell, J. (2007). Collaborative Design Using a Shared IFC Building Model-Learning from Experience. Automation in Construction, 16: 28-36.

RICS. (2012). RICS New Rules of Measurement 1: Order of Cost Estimating and Elemental Cost Planning. Coventry: Royal Institution of Chartered Surveyors (RICS).

Sabongi, F. J. and Arch, M. (2009). The Integration of BIM in the Undergraduate Curriculum: an analysis of undergraduate courses. Retrieved from: http://ascpro0.ascweb.org/archives/cd/2009/paper/CEUE90002009.pdf.

Sylvester, K. E. and Dietrich, C. (2010) Evaluation of Building Information Modeling (BIM) Estimating Methods in Construction Education. Retrieved from: http://ascpro.ascweb.org/chair/paper/CEUE221002010.pdf.

Taylor, J. M., Liu, J. and Hein, M. F. (2008). Integration of Building Information Modeling (BIM) into an ACCEAccredited Construction Management Curriculum. Retrieved from: https://fp.auburn.edu/heinmic/Pubs/ASC%202008-Integration.pdf.

Thurairajah, N. and Goucher, D. (2012). Usability and Impact of BIM on Early Estimation Practices: A Cost Consultant's Perspective. Paper Presented at the International Congress on Construction Management Research, Montreal.

Withers, I. (2014). RICS: BIM will 'Enhance QS Role'. Retrieved from: http://www.building.co.uk/rics- bim-will-enhance-qs-role/5066168.article.

Wu, S., Wood, G., Ginige, K. and Jong, S. W. (2014). A technical review of BIM based cost estimating in UK quantity surveying practice, standards and tools. Journal of Information Technology in Construction (ITCon), 19. pp. 534-562. ISSN 1874-4753.