A CASE STUDY OF FOSTERING MULTIDISCIPLINARY IN BUILT ENVIRONMENT USING BIM

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Building information modelling (BIM) has been made mandatory as part of the public procurement process in the UK. This move will by default encourage SMEs to develop their own capabilities to work with BIM technologies in order to maintain their market share or gain competitive advantage. It is argued that graduates with BIM expertise will be high in demand and will also have a profound effect on the sector and high project performance. This paper argues that the industry should look to the construction related education providers to instil students with awareness of BIM concepts and principles. This trend must be underpinned by educating and training BIM users and preparing future industry participants by modifying the curricula of architecture, engineering and construction and construction related programmes. The research will use case study approach to capture data from key staff, students and documentary evidence from two universities, one in the north-east and the other in the north-west. The paper will outline issues encountered and make recommendations on how best to improve the curriculum. The outcome will lead to the development of a strategy of how BIM activities can be incorporated in an effective learning methodology for both staff and students.

Keywords: building information modelling, best practice, assessment, teaching and learning.

INTRODUCTION

The construction industry is vital to the economies of most developed countries. Despite its importance, it has been established that productivity has declined over the past three decades and that the industry is extremely inefficient compared with other industries (Briscoe and Danity, 2005). The construction industry has also been described as extremely fragmented and lacking collaboration between supply chains (e.g. Latham, 1994; Egan, 1998, 2002). Researchers working in this area have shown that the quality of project delivery has declined over the past 20 years and that poor delivery is contributing to the increase in project costs (Liu *et al*., 2011; Ilozor and Kelly, 2012; Singh and Holmström, 2015). In the light of the delivery issues, changes have been recommended that would involve integration of supply chains and also promote collaboration. Many proponents have identified BIM as a technology and process that can create value within supply chain and promote learning. BIM is a visual database of building information and it supports integrated design and construction process. It has been shown that the proper use of BIM can improve quality of construction, reduce project delivery time, and reduce construction claims and support sustainable construction (Eastman *et al*., 2008; Volk *et al*., 2014). Uptake of BIM technology is also encouraged by recent push towards sustainability, lean construction and drive towards concurrent ways of working. BIM technology and

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processes are increasingly being seen as key enablers for realising a collaborative working environment, by enabling multiple disciplines to work together using a shared building model. In the UK, BIM is increasingly being seen not just as a technical process to determine the likely performance of projects but a valuable tool in the mediation between many associated stakeholders with their differing visions, numerous requirements and variation in their expertise, and as a valuable process to promote learning and managing information (Smith and Tardif, 2009; Succar, 2009; Gu and London, 2010; Jung and Joo, 2011; Ilozor and Kelly, 2012).

The emerging role presents new and considerable challenges for Architecture, Engineering and Construction (AEC) industry and more importantly the training providers. MacDonald and Mills (2011) identified that current AEC education in the UK rarely involved collaboration between students training for the AEC professions. There has been a demand from AEC academic providers to develop project-based modules to mimic real-life construction projects involving close collaboration between multiple disciplines. Attempts to integrate multiple construction disciplines using various curricular developments have been going on for almost a decade (e.g. Fruchter, 2003). However, the education sector is falling behind in this respect. The use of BIM is widely recognised as having the potential to change the way building projects are run by facilitating collaborative working practices that engage all design team members at an earlier stage in the design process, aided by BIM tools. Currently, graduates with collaborative design skills and BIM expertise are in high demand to develop innovative and collaborative working practices using BIM. Resultantly, there is a growing interest in using BIM as a core to enhance inter-disciplinary collaborative working within AEC education. Because of the growing influence of BIM, Mulva and Tisdel (2007) rightly define BIM as a *"new frontier for construction education"*.

To address these needs and to provide students with an opportunity to work on a realistic construction project, there is a gradual and consistent push toward adoption of BIM in the under-graduate/post-graduate curricula and a number of project based single/multi-disciplinary project based modules have been launched within two northern universities. Some of these modules involve students from multiple disciplines including Building Services (BS), Construction Management (CM), Architectural Design Technology (ADT) and Quantity Surveying (QS) working together, while other modules involve close collaboration between students from a single discipline. Also, across different modules, students are being encouraged to deliver their project work using BIM technology.

Authors' experience of teaching and assessing inter-disciplinary and multiple disciplinary modules shows that collaboration amongst students often takes place at a superficial level. In examining the current status of engineering education by Huntzinger *et al* (2007), a striking pattern emerges in the form showing that the curriculum lack relevance to actual practice. As graduates of engineering education system, authors' can attest to the vast disconnect between engineering curriculum and the actual practice. The importance of connecting the curriculum to the society is well documented in research work by DeHaan (2005); Wong *et al* (2011); Richards and Clevenger (2011); Gutierrez (2014). As a result, the assumed collaboration AEC education has a tendency to take place on a very superficial level, leaving students unaware of the connection between the curriculum and the actual practice. Students address simple elements out of context. It is difficult to see how individual elements relate to the whole building and interact with one another e.g. linking construction schedule to design model or linkages between quantity take-off and actual design. In essence, true spirit of multi-disciplinary collaborative working is often not achieved. Also, the way students operate in multi-disciplinary modules does not mimic environment of collaboration and the actual working methodologies found in construction practice. The entire vision of the exercise to bring in different perspectives and different set of goals from multiple disciplines are not adequately achieved. Traditionally Architects have focused on building design, CM have focused on management of construction process, QS have focused on cost and take-offs. Curriculum was developed to reflect such domain focus. A key objective of multi-disciplinary modules is to enable students to see how there discipline-specific work fits in with the whole. However, with different disciplines not integrating well, this vision is often not achieved.

This paper investigates existing challenges in facilitating multi-disciplinary collaboration between built environment students and determines the integrative potential of BIM technology to enhance multi-disciplinary collaboration. The subsequent sections assess and evaluate relevant literature to enable an understanding of BIM development in construction field, the benefits that it could offer to the construction industry as well as identifying the barriers that prevent adoption. The final section will discuss the existing research in BIM diffusion in academia. A key focus is on determination of best pedagogic approaches that needs to be adopted and key issues that need to be addressed to enhance multi-disciplinary collaboration using a shared building model.

LITERATURE REVIEW

The construction process and its success are influenced by various factors and choosing the most effective investment to improve the construction process is a very important decision. Popov *et al* (2010) identified that the growing diversity of disciplines, professionals, tasks, events in respect of the management during design and construction stages of projects, plus the more competitive cost, time targets coupled with higher quality expectations and the need for enhancing technology are the driving force of information modelling in the construction industry.

Barlish and Sullivan (2012) explained that the application of BIM has become more accepted and common throughout the industry, but there are majors issues with the concept because of difficulties in both its definition and application. They stated that because the term BIM is often used by vendors for their marketing strategies, the definition of BIM has become confusing. Liu *et al* (2011) identified that BIM has evolved from CAD research and suggested that in order to avoid the complexity; they defined BIM in different terms from Model and design data to construction management. This research defines BIM as a model and a methodology. From a model perspective, BIM is a digital model of a building in which data about the building is stored and structured in such a way that the data can be shared between the project team (BSI, 2010). From a methodology standpoint, BIM is an enabling technology with the potential for improving communication among project team, improving the quality of information available for decision making, improving the quality of services delivered, reducing cycle time, and reducing cost at every stage in the life cycle of a building (Smith and Tardif, 2009). Succar (2009) noted that regardless of the different definitions and approaches to BIM, all definitions focus on the fact that BIM is a catalyst for change poised to improve collaborative working among project team, improve its efficiency/effectiveness and lower the high cost of inadequate interoperability. These potential benefits are compelling enough for construction organisation and academic providers to adopt BIM principles and concepts.

There have been several BIM education approaches and applications of BIM diffusion in education are currently in place in various academic institutions. The BIM education approaches cut across various disciplines and sectors including construction, engineering, manufacturing and employing variety of strategies and concepts and the vast majority of these approaches focus on student-centred BIM curriculum development, BIM integration approach into construction curriculum and collaborative design and construction (Wong *et al*., 2011). There is a consensus in literature that BIM education in universities are timely and appropriate in order to respond to industry challenges. It is widely acknowledged that introducing and incorporating BIM education in universities can yield very productive results for both students and employers.

There are a few on-going multi-discipline courses in UK and in other countries (e.g. Taiebat and Ku, 2010; Wong *et al*., 2011; Clevenger *et al*., 2012; Mandhar and Mandhar, 2013; Gutierrez, 2014; Underwood and Ayoade, 2015). Wong *et al* (2011) further stated that academic institutions in many countries have started teaching BIM and have set up curricula for the integration of BIM into the existing courses related to the AEC industry. Although literature review reveals that there is a proliferation of BIM education diffusion in both academia and industry, however; in the UK the academic adoption are still patchy and limited to a very few universities. For the UK to fully diffuse BIM in the curricula, fundamental changes are required to address the issues that are associated with multi-disciplinary programmes. This research will investigate the best ways for BIM diffusion can be implemented in the UK universities and the challenges that come with it. The intention of the research is to develop a programme that facilitates collaborative working amongst multi-disciplinary students in the AEC field.

RESEARCH METHODOLOGY

The research adopted a case study approach to examine BIM diffusion in the curricula in the two universities. As part of the case study, a series of six semi-structured interviews were conducted with tutors and users in the two northern universities, particularly those involved in multi-disciplinary module delivery. A purposive sampling strategy was employed, selecting tutors and users with experience in BIM and collaborative working practices. Because this research is part of a larger research which aims to investigate BIM in curriculum development, the interviews were supplemented by the collection of materials from the larger research. Interview questions were directed towards current BIM practices in the two universities. During the interviews, the greater involvement and participation of the interviewees were essential to explore key issues in adopting BIM for multi-disciplinary courses. Thus, interviews were loosely structured. According to Fellows and Liu (2003), the advantage of loosely structured interviews is that more complex issues can be probed, answers can be clarified and a more relaxed research atmosphere may result in more in-depth as well as sensitive information. The disadvantages are that the data are time consuming and difficult to collect and analyse and there are greater opportunities for interviewer bias to intervene. In this case, advantages far outweigh the disadvantages. During the interviews, discussion primarily revolved around key issues as it relates to the BIM diffusion in the curricula. During the interviews, the topics under discussion were elaborated upon using laddering techniques, to avoid getting standard answers.

Laddering is a tool for uncovering subjective causal chains in qualitative interviews (Grunert and Grunert, 1995). In laddering, a series of consecutive probes are used to prompt the respondents to develop causal chains. Critical reflections also played a key role in the research process. Whilst interviewees provided insights regarding the methodologies and strategies of BIM practices in the universities, it also provided the challenges and barriers that exist in the current practices. The interviews were undertaken in early 2012 and middle 2012, during the initial study of BIM diffusion within the two universities. Whilst this small sample size does not allow for generalisation, it will provide insight as to the current perception of those teaching in this field, and their understandings of BIM application in the curricula. The interviews were digitally recorded, transcribed verbatim and subsequently coded using content analysis, to highlight consistencies and inconsistencies, patterns and themes (Silverman, 2001; Langdridge, 2005). Consequently, the findings have been developed into a narrative to construct a contemporary picture of BIM practices in the two universities.

RESULTS AND ANALYSIS

It is important to build learning on sound pedagogical principles. Confucius (450BC) rightly identified the need for an appropriate pedagogical process, when he wrote: *"Tell me, and I will forget, show me, and I may remember, involve me and I will understand"*. In order to achieve goals of multi-disciplinary collaboration, it is important that students from different disciplines work with a shared building model, analysing building data in varied ways to satisfy needs of their specific discipline (Figure 1). Authors' observation of assessments of outputs in multi-disciplinary project shows that collaboration usually takes place only at a superficial level. For instance, in true sense there is little integration between construction schedules (CM deliverable) or quantity estimates (QS deliverable) and the building model (ADT deliverable). In a recent assessment exercise undertaken for Disciplinary Project Students, the author observed that students came up with widely varying estimates ranging from £1 million to £6.5 million for construction of a new building block. Quizzing students showed lack of essential quantitative and analytical skills amongst students. The dearth of quantitative and mathematical skills amongst engineering under-graduate students have been highlighted in various research studies and often attributed to decrease of entry level into the profession (e.g. Newman-Ford *et al*., 2007; Overton, 2003).

Aforementioned concerns were addressed via involvement of professional practising jury in design, development, delivery and assessments of modules coupled with selection of real-life local projects at University of Salford. In addition to fulfil various academic assessment requirements, student teams were required to make formative and summative presentations to jury members and project stakeholders. This resulted in positive feedback related to enhancing student experience and in bridging the gap between academia and practice. Feedback from module evaluation included student comments such as: *"A local project provides a realistic feel. We can actually go to the site and explore the project ourselves. Such level of detail is not possible using a scenario-based make believe project"*. Another student highlighted that working on a real-life project help them build their project portfolio and help improve CV. Such observations are also supported by reviewing the relevant literature. In view of many experts, such problem-centred and project-focused teaching is fundamental to the teaching for collaboration (Boomer *et al*. 1992; Jordan, 1995). Such real world problem based approaches help students to become active learners and encourage deeper learning, as highlighted by comments of one the interviewed tutors, *"Hypothetical scenario based project exercises are good for classroom learning. However, to prepare students for professional practice, it is important to have more complex real-world projects"*.

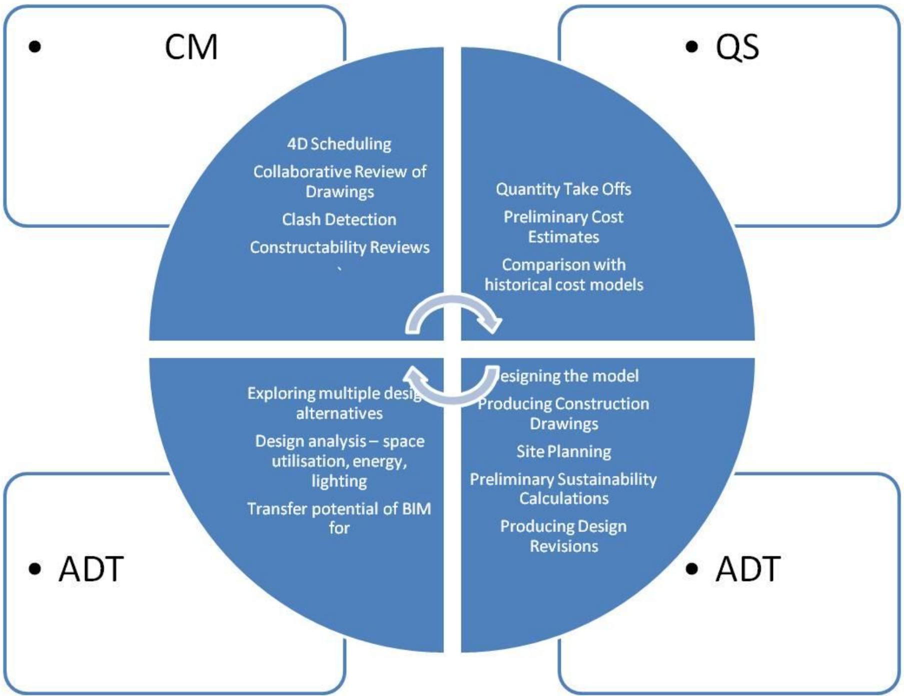

Figure 1: Integrating multiple disciplines using BIM

A key focus of this paper is to investigate various pedagogic approaches related to BIM-based model sharing. During the course of this action project, two separate teaching approaches were tried i.e. Bottom-Up (where students were provided to develop BIM models from scratch based on client's brief) and Top-down (students were provided with an existing building model and asked to bring in interventions based on discipline specific needs). In bottom-up teaching strategy, students designed building super-structure, sub-structure, finishing and in the process, learned about key features of the BIM authoring tools and fundamental modelling concepts. Certain challenges were encountered while utilising bottom-up teaching strategy with multi-disciplinary teams where students worked in a linear or sequential manner.

Other disciplines (QS, BS, CM) rely on Architectural Design Technology (ADT) students to deliver the project design prior to executing their disciplinary tasks. Any delays by ADT students had a knock-on impact on multi-disciplinary students (QS, BS, CM), often resulting in team-conflicts and strain. There are certain challenges involved in teaching non-ADT students skills in model development. Firstly, use of BIM software is complex and understanding the ins and outs of a particular tool may take years of experience. Secondly, there are time constraints involved with limited number of class hours. The author used a lecture-lab combined delivery approach, where conceptual topics were covered in the first half, while computer-based work using hands-on instructions was carried on in the second half. During the lab session, the author observed varying level of technical competence amongst students. While some students were able to draw or manipulate the model using given set of instructions, others would struggle with basic tasks.

In contrast, in a Top-Down teaching strategy, there is no time-lag involved as a working building model is provided as part of the assessment brief. Thus, all disciplines simultaneously hit the ground running, focusing on their discipline specific interventions. Provided building model serves as a test-bed and provides students with an opportunity *““to flex their cognitive and social muscle in an environment where anything is possible and experimentation is safe, permissible, and desirable”* (Galarneau and Zibit 2007, p. 81). Top-down teaching approach works well with new students with little or no knowledge of the BIM technology. Also, provision of existing model helps to teach students fundamentals of modelling at a conceptual level. Once aware of the conceptual approaches and fundamentals of the tools, support is made available (e.g. online software tutorials) where students can self-teach to an advanced level. Another key advantage of providing students with a developed BIM is that visualisation plays a key role in generating student’s interests and makes them passionate about the subject area. This is also highlighted by an interviewee comments i.e. *“It is important for students to know their own discipline area. However, at the same time, awareness of what others is doing and how their work fits in the big picture, is important”*. Quite a few interviewees’ highlighted the fact that students put a lot of emphasis on applications and tools side, while not adequately addressing the conceptual or process related issues of multi-disciplinary collaborative working. This is highlighted by the following comment, *“It is important to address conceptual side of the multi-disciplinary process. Students often lack an understanding of key issues involved in multi-disciplinary collaboration”*. Use of appropriately software tools to enable students to correctly develop and visualise building objects, accurately extend the model, organisation of the model and development of information exchange standards to enable multi-disciplinary model based communication are important skills for students to have. Students lack of grasp of relevant software tools often lead to a compromise in accuracy and detailing of the building model. It is important to teach students key skills to enable professional use of the software.

CONCLUSIONS

Using a BIM-based shared building model approach helps to improve students’ understanding of the engineering design process, their ability to do discipline specific design using a shared model, helps improve communication skills using engineering drawings. It also helps them better integrate design model with cost and time.

The key benefits for using a BIM-based shared building model for multidisciplinary collaboration is discussed in detail throughout this paper. However, it is important to keep in perspective that using a shared building model approach, there is a potential to support a wider educational agenda. Firstly, the visual 3D models has the potential to generate deeper learning, by generating student interest and by helping them set their own learning agenda working together with other users and practitioners. Secondly, visual models help to improve student communication skills as they can more easily relate to a model. Better communication eventually leads to better teamwork, collaborative work and development of leadership skills. Lastly, using a BIM-based collaborative approach is a great way to bridge the gap between academia and industry. In exploring an analytical building model, students develop problem solving, quantitative and analytical skills make key judgments and decisions. Such skills help them in their development as a professional. BIM is an evolving technology and its adoption in curriculum taught at the two northern universities are still at preliminary stages. The authors intend to continue with the research process, to ensure that emerging BIM technology is best aligned to the needs of the industry and students.

REFERENCES

Augustsson, G. I. (2007) *“Building Information Modeling and the impact on the building industry”*. Copenhagen: Copenhagen Technical Academy [Online]. Available at: http://www.fsr.is/lisalib/getfile.aspx?itemid=4006 (Accessed: 1ST May,2013).

Barlish, K. and Sullivan, K. (2012) How to measure the benefits of BIM – a case study approach, *“Automation in construction”*, Vol. **24**, pp. 149-159.

Boomer, G., Lester, N. and Onore, C. (1992) *“Negotiating the Curriculum”*. Bristol, PA: Falmer Press.

Briscoe, G., and Dainty, A. (2005) Construction supply chain integration: an elusive goal?. *“Supply chain management: an international journal”*, **10**(4), 319-326.

BSI (2010), *“British Standards Institution, Constructing the business case –BIM”*, British Standards Institution and Building Smart, UK.

Chikofsky, E. J.; Cross, J. H., II (1990) *“Reverse Engineering and Design Recovery: A Taxonomy”*. IEEE Software Vol **7** No.1, pp 13–17.

Clevenger, C. M., Ozbek, M. E. and Glick, S. (2010) Integrating BIM into construction management education, *“Ecobuild”*, America, Washington D.C.

Clevenger, C., Glick, S., AP, L. and del Puerto, C. L. (2012) Interoperable learning leveraging building information modeling (BIM) in construction education, *“International Journal of Construction Education and Research”*, Vol. **8**, No. 2, pp. 101-118.

DeHaan, R. L. (2005) The impending revolution in undergraduate science education, *“Journal of science education and technology”*, Vol.**14**, No.2, pp. 253-269.

Eastman,C., Teicholz, P., Sacks, R., Liston, K., (2008) *“BIM Handbook. A Guide to Building Information Modelling for Owners, Managers, Designer, Engineers, and Contractors”*. Hoboken, NJ: Wiley.

Egan, J. (1998) *“Rethinking Construction”*, Construction Task Force Report for Department of the Environment, Transport and the Regions.

Egan, J. (2002) *“Accelerating Change, Strategic Forum for Construction”*, London, Consultation Paper.

Fellows, R. and Liu, A. (2008) *“Research Methods for Construction”* 3rd Edition, Oxford, UK; Malden, USA: Blackwell.

Fruchter, R. (2003) Innovation in Engaging Learning and Global Teamwork Experiences, In: *“Proceedings of the 4th Joint International Symposium on Information Technology In Civil Engineering”*, 2003, Nashville, TN.

Galarneau L, Zibit M (2007) Online games for 21st century skills In: Conole G, Oliver M (Eds) *“Contemporary Perspectives in E-Learning Research: Themes Methods and Impact on Practice”*. Routledge, London.

Grunert, K.G. and Grunert S.C. (1995) Measuring subjective meaning structures by the laddering method: Theoretical considerations and methodological problems, *“International Journal of Research in Marketing, Vol. **12**, pp.209-225.*

Gu, N. and London, K. (2010) Understanding and facilitating BIM adoption in the AEC industry, “Automation in construction”, Vol. **19**, pp. 988-999.

Gutierrez, M. (2014) Reorienting innovation: transdisciplinary research and building technology, *“Architectural Research Quarterly”*, Vol. **18**, pp 69-82, DOI: 10.1017/S1359135514000372.

Huntzinger, D. N., Hutchins, M. J. , Gierke, J. S. and Sutherland, J. W. (2007) Enabling sustainable thinking in undergraduate engineering education, *"International journal of engineering education"*, Vol.**23**, No.2, pp. 218-230.

Ilozor, B. D. and Kelly, D. J. (2012) Building information modeling and integrated project delivery in the commercial construction industry: a conceptual study, Journal of engineering, project, and production management, Vol. **2**, No. 1, pp 23-36.

Jordan R. N. (1995) Negotiating to Learn: A Beginning. PASSAA. *"A Journal of Language Teaching and Learning in Thailand"*, Vol. **25**, pp 91-99.

Jung, Y. and Joo, M. (2011) Building information modelling (BIM) framework for practical implementation, *"Automation in construction"*, Vol. **20**, pp 126-133.

Latham, M. (1994) *"Constructing the Team"*, HMSO, London.

Liu, Z.; Osmani, M.; Demain, P. and Baldwin, A. N. (2011) The potential use of BIM to aid construction waste minimisation, *"Proceedings of the CIB W78-W102 2011: International conference"* - Sophia Antipolis, France 26-28 October.

Macdonald, J. A. and Mills, J. E. (2011) The potential of BIM to facilitate collaborative AEC education, *"America Society for Engineering Education Annual Conference"*, Vancouver, Canada, June 26-29, 2011.

Mandhar, M. and Mandhar, M. (2013) BIMing the architectural curricula: integrating BIM in architectural education, *"International Journal of Technology and Design Education"*.

Mulva, S. and Tisdel R. (2007) BIM: a new frontier for construction engineering education. *"American Society for Engineering Education"*, 2007.

Popov, V., Migilinskas, D., Juocevicius, V. and Mikalauskas, S. (2010) Application of BIM and Construction Process Simulation Ensuring Virtual Project Development Concept in 5D Environment', in *"25th. Intl Symposium on Automation and Robitics in Construction"* Vilnius Gediminas Technical University Publishing House *"Technika"*.

Richards, E. L. and Clevenger, C. M. (2011) Interoperable learning leveraging building information modeling (BIM) in construction management and structural engineering education, *"Associated school of construction, Proc. 47th annual conference"*.

Singh, V. and Holmström, J. (2015) Needs and technology adoption: observation from BIM experience, *"Engineering, Construction and Architectural Management"*, Vol. **22**, No. 2, pp 128-150.

Smith, D. K. and Tardif, M. (2012) *"Building information modeling: a strategic implementation guide for architects, engineers, constructors, and real estate asset managers"*, 1st Edition, John Wiley and Sons, US.

Succar, B. (2009) Building information modelling framework: a research and delivery foundation for industry stakeholders, *"Automation in Construction"*, Vol. **18**, pp 357-375.

Taiebat, M. and Ku, K. (2010) Industry's expectations of construction school graduates' BIM skills, *"Associated school of construction, Proc. 45th annual conference"*, University of Florida, Gainesville.

Underwood, J. and Ayoade, O. (2015) *"Current position and associated challenges of BIM education in the UK higher education"*, BIM Academic Forum (BAF), ISBN 9781907842641.

Volk, R., Stengel, J. and Schultmann, F. (2014) Building Information Models (BIM) for existing buildings - literature review and future needs, *"Automation in Construction"*, Vol. **38**, pp 109 - 127, DOI: 10.1016/j.autcon.2013.10.023.

Wong, K. A., Wong, K. F. and Nadeem, A. (2011) BIM for tertiary construction education in Hong Kong, *"Journal of Information Technology in Construction"*, Vol. **16**, pp. 467-476.