TOWARDS INTEGRATION OF BIM INTO CONSTRUCTION MANAGEMENT CURRICULUM LEARNING ACTIVITIES

Z. A. Krezel, N. Y. Osman-Schlegel and M. R. Hosseini

ABSTRACT

The utilization of Information and Communication Technology (ICT) by the construction industry and transformations in work practices, such as implementation of Integrated Project Delivery (IPD), have proven to increase construction productivity and efficiency in the delivery of building projects. The education of the construction professionals has now instigated the use of highly collaborative teaching methods reinforced by extreme utilization of ICT to increase the efficiency of information distribution and knowledge development.

Building Information Modeling (BIM) methodology, which integrates advanced ICT with stakeholders' collaboration, has emerged as one of the most effective project development and delivery methods currently available within the AEC industry. Increasingly, construction managers become involved in BIM methodology due to its capabilities of simulating and assisting the project management processes. The technology portion of the BIM methodology integrates software usage with design, analytical and simulation capabilities to produce interoperable information outputs for productive use by project stakeholders. The collaboration instigated by the BIM methodology enables integration of modeling information and stakeholder ideas in order to produce a Virtual Design and Construction (VDC) platform.

This paper introduces learning methodology based on BIM concept and IPD philosophy in regards to its higher education application within the construction project management discipline. The usage of the Learning Management System (LMS) utilized as the learning dissemination platform was compared between comparable learning units to evaluate the contribution of BIM methodology to effectiveness of the learning processes and its impacts on expected outcomes. The paper concludes that BIM methodology supplemented by IPD provides unique opportunities to develop and manage knowledge.

Key words: *BIM methodology, construction project management, virtual collaboration, knowledge management.*

1 INTRODUCTION

Building Information Modeling (BIM) is a relatively new methodology for delivery of building projects based on the extreme collaboration, virtual integration of modeling efforts by project stakeholders supported by the use of advanced Information and Communication Technology (ICT). BuildingSMART, (2012) defines BIM methodology as "a process of virtual representation of building over its whole life cycle from planning, design, construction, operation, maintenance and de-construction" and "a framework for collaboration in a multidisciplinary environment that brings together all the parties that design, construct and operate a facility" Autodesk, (2014) defines BIM as "an intelligent model-based process that provides insight to help plan, design, construct, and manage buildings and infrastructure".

The Australian Architecture, Engineering and Construction (AEC) industry 'wait and see' approach to the invasion of BIM methodology is evidenced by relatively low level of awareness and utilization amongst stakeholders of building projects. Although, the low utilization of BIM methodology is partially attributed to the project sponsors strategic approaches and explicit requirements, one of the major reasons for the low utilization is the inadequate level of BIM skills amongst the industry professionals (NATSPEC, 2014). The 2013 survey of the AEC firms in Australia and New Zealand, concluded that on average, only 51% are engaged in BIM on more that 30% of their projects. There is also a significant disparity in BIM implementation, which is led by the design (architecture and engineering) firms with 61% currently using BIM methodology. However, only 33% of construction professionals are in the same category of BIM users (McGraw-Hill Construction, 2014).

The utilization rate by the AEC professionals is not only dependent on current skills set but also on their ability to adapt to new technologies and collaborative work practices. The skills gap and apparent resistance of construction industry to process changes were the major obstacles identified in the 2010 study on the impact of BIM on productivity in the Australian building network (Allen Consulting Group, 2010). The stakeholders of the AEC industry perceive cost of implementing BIM compatible technology, start-up and administrative cost, cost of education and training, as well as, cost of behaviuor change as excessive. However, this argument might not be valid as investment in new technologies and/or collaborative work practices such as BIM methodology is ordinarily compensated by higher Return on Investment (ROI).

The McGraw-Hill Construction, (2009) report on the business value of BIM in the USA concludes that the 70% of all companies using BIM methodology reported positive ROI and the 87% of expert users measured positive ROI resulted from the BIM implementation on their projects. The latest study of the design (A&E) and construction (C) companies in Australia and New Zealand who use BIM methodology on their projects concludes that the 36% perceived high positive (>25%) ROI and the 46% of the high-implementation level users (more that 60% of their projects are BIM driven) who measure ROI, reported a very high positive ROI (McGraw-Hill Construction, 2014). The report concludes that the three major contributors to the highly positive ROI influenced by the BIM methodology are (1) the improved project processes, (2) better project stakeholder communication, and (3) improved productivity of personnel. These three aspects are directly related to the extreme collaboration between the AEC professionals who are BIM-skilled and equipped with smart BIM technology. However, the 2014 report also advocates that the industry must focus on (1) investing in the development of collaborative skills and BIM processes improvements with external parties, including clients and suppliers (2) upgrading their ICT to the BIM compatibility standards, and (3) providing more opportunities for BIM training. In regards to the construction sector of the AEC industry, the report recommends an urgent action by (1) investing in the development of BIM skills by construction professionals, (2) implementing collaborative practice in the high-value construction activities such as the multi-trade coordination and model integration, as well as (3) investing in the BIM capability growth by sub-contractors (McGraw-Hill Construction, 2014).

At the same time when the AEC industry realizes opportunities and challenges associated with the BIM methodology, the discipline leaders, research organizations and academic institutions have been developing strategies and practical ways of implementing BIM-driven higher education.

The 2013 report on the ‘AEC education using BIM’ by the Australian Government Office of Learning and Teaching (OLT), concludes that an enormous culture shift is needed, not only in the AEC industry, but most importantly, in the higher education sector in order to prepare BIM-capable generation of the AEC professionals. The 2013 survey of thirty (30) accredited Australian universities revealed that eleven (11) universities offer the BIM-supported courses in architecture; however, only five (5) in the combined architecture an engineering (A&E) or architecture and construction (A&C)

disciplines, which also include the three (3) universities (UON, UniSA, UTS) planning to offer collaborative BIM, encompassing all three AEC disciplines.

The OLT, (2013) also concludes that as the result of the AEC students being educated within separate disciplines, the graduates have limited understanding of the AEC's 'big picture', complexity of modern professional practice in the industry as well as limited ability of embracing the 'real' collaboration and productive involvement on complex, large-scale projects. These limitations are attributed mainly to the resistance of academia in embracing multidisciplinary, collaborative educational methodologies that necessitate architectural, engineering and construction project management students working together in a classroom or in the virtual environment on industry grounded projects. In addition to the request for the cultural modifications, the report identifies an urgent need for the development of relevant BIM-skills by the AEC academics. The IMAC (Illustration, Manipulation, Application, Collaboration) Framework for inclusion of BIM in the architectural, engineering and construction project management curricula is proposed by the OLT.

2 FRAMEWORK - IMAC FRAMEWORK FOR CONSTRUCTION PROJECT MANAGEMENT EDUCATION

The IMAC Framework proposes four integrated stages of BIM supported education for each AEC discipline; illustration (I), manipulation (M), application (A) and collaboration (C). At any stage if BIM implementation under the IMAC Framework, a specific AEC discipline focuses on development of the discipline explicit BIM attributes in five common areas: (1) knowledge of building technology, (2) understanding of environment (materials and sustainability), (3) management, (4) IT and (5) specialization. Specifically, directed at the Construction Management (CM) discipline, the IMAC Framework recommends the BIM methodology targeting two stages: the illustration (I) of building technology, materials, sustainability, fundamentals of architecture and engineering, and the collaboration (C) by integration of the IT/BIM tools in the management of construction processes, involvement and management of stakeholders and project multi-disciplinary teams, and the management of project communication, information and knowledge systems.

The 3D architectural and engineering models are recommended to be used in illustrating the key concepts and technical information about buildings and infrastructure. The 3D, intelligent, data-reach models, which contain all technical information needed to procure, design and construct a building are proposed as a modern alternative to the standard 2D design documentation and traditional methods of buildings visualization. Most importantly the 3D, BIM models are to become the electronic, integrated educational tools, and the single source of information substituting hundreds of pages of technical specifications, design drawings currently forming the 2D design documentation that is dispersed by location and ownership amongst the AEC industry professionals.

The IMAC Framework proposes the use of the 4D (+time) and 5D (+cost) BIM models in the development of integration and collaborative competencies of the construction project management students. The 4D and 5D models integrate the core activities of construction management including the development and control of construction processes, and allocation and expenditure of project resources. The BIM models become virtual learning tools allowing analysis of designs from the constructability perspective and iterative simulation of construction processes, which in case of the CM students increases efficiency of learning. The models are also to be used for developing attributes in the management of project stakeholders and project information, necessitating collaboration with the architecture, engineering, quantity surveying and building surveying students.

3 METHODOLOGY - BIM EMBEDDED BACHELOR OF CONSTRUCTION MANAGEMENT (BCM) PROGRAM

The School of Architecture and Built Environment at Deakin University is one of the 37% of Australian universities, which are already involved in BIM supported education. The School provides accredited programs in the majority of professional disciplines in the AEC, amongst other including urban planning, architecture, construction projects and facility management. The flagship undergraduate program, which is a workable example of the multidisciplinary approach to the AEC education, is the combined degree in architecture-and-construction management. In response to the growing pressures by accrediting professional institutions and expectancies of the Australian AEC industry for BIM-ready graduates, the School developed and implemented an educational methodology for BIM-supported training of the CM students.

The methodology is guided by the principles of the IMAC Framework and is applied to the 50% of the BCM program. Sixteen (16) learning units are selected for inclusion of the BIM methodology. Selected BIM-embedded units develop (1) the knowledge of building technology including the structural systems and MPE (mechanical, plumbing and electrical) services in the early stages of the program, (2) knowledge of planning and resourcing building projects throughout the mid-program stages, and (3) the knowledge of project management, collaboration and integration throughout the final stages of the BCM program. The professional knowledge development in these units is based on eight (8) BIM models representing typical building systems, ranging from a simple shed to a high-rise building. Figure 1 presents the BIM models used as learning resources embedded in the BCM program.

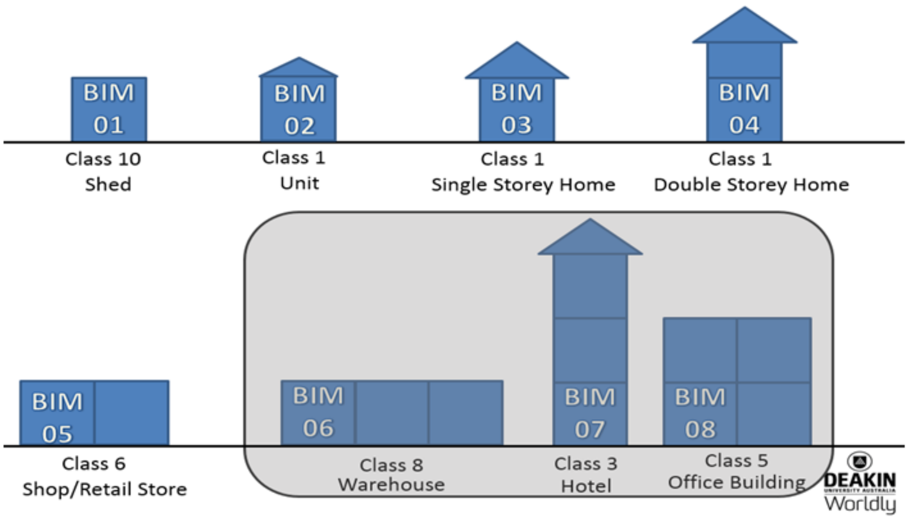

Figure 1. BIM models embedded in the BCM program

The University's Learners Management System (LMS) is used to communicate the eight intelligent BIM models with students enrolled in a particular learning unit. The models are repositories of intelligent information generated by architects, engineers, environmental consultants, quantity surveyors, schedulers and construction project managers. Figure 2 presents the information repository system.

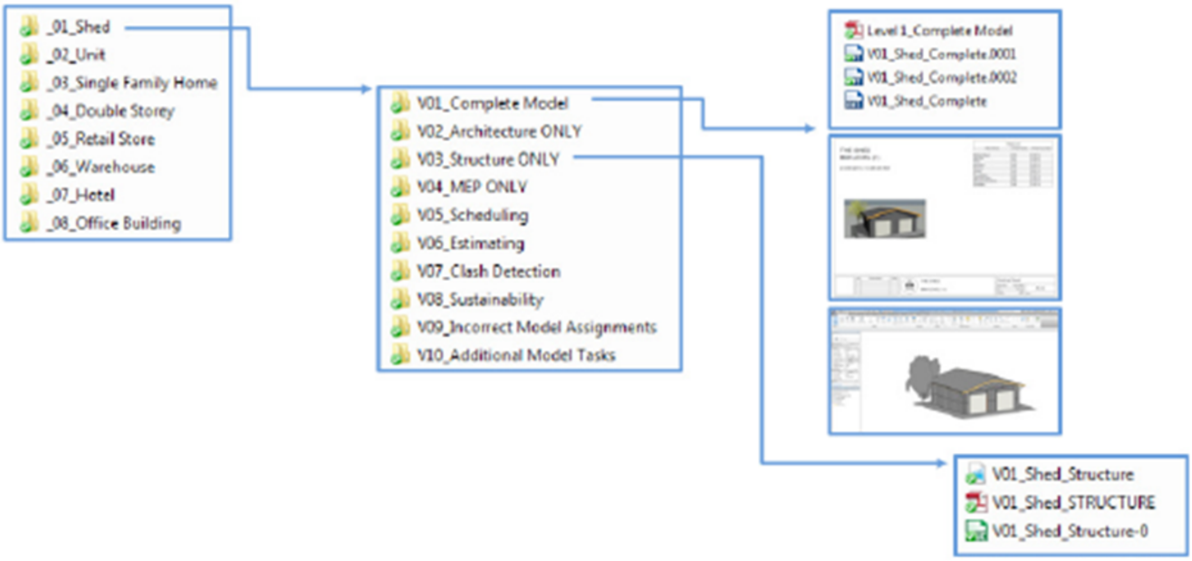

Figure 2. BIM models information repository systém

The models are also used for assessment tasks in each of the sixteen units, testing the development of the core professional knowledge and skills as well as ability to operate within the BIM methodology. Individually, every BIM model integrates a number of learning units focusing on various aspect(s) of a building project embedded within the model's information database.

4 IMPLEMENTATION - MODEL DEVELOPMENT AND MODEL INTERACTION

The BIM-embedded methodology has been implemented in the 2014 academic year in a number of learning units. At the first-year stage of BIM-embedded education it is planned that the 80% of student's effort is devoted to the development of virtual models and the 20% to the model interaction. Students, at this stage, are not required to use BIM model for other purposes such as estimating, scheduling, clash detection amongst other. At the start of the program in the first trimester, the SRT159 (Construction Projects 1) unit introduces the first year students to a building project sponsored by an industry partner. In the second trimester, other two learning units use the same building project to further develop the knowledge of relevant building technology and to advance the student's collaborative attributes. The SRM165 (Information Systems in Construction) unit focuses on the virtual system thinking, BIM technology and the BIM necessitated collaboration, whereas the SRT259 (Construction Projects 2) unit centers on the traditional system thinking, well-established technologies and conventional collaboration. In 2014, the common project in these units was a two-storey brick-veneer building (Balmoral-402). The industry partner provided the standard 2D documentation of the building, also organized site visits, delivered guest-lecture presentations and participated in the assessment of building models produced by the students in the two learning units. The SRT259 model was a physical model built from Balsa wood (see Figure 3a), whereas the SRM165 model was the 4D virtual model. Figure 3b presents 3D component of the virtual model and Figure 4 presents the time integrated BIM model.

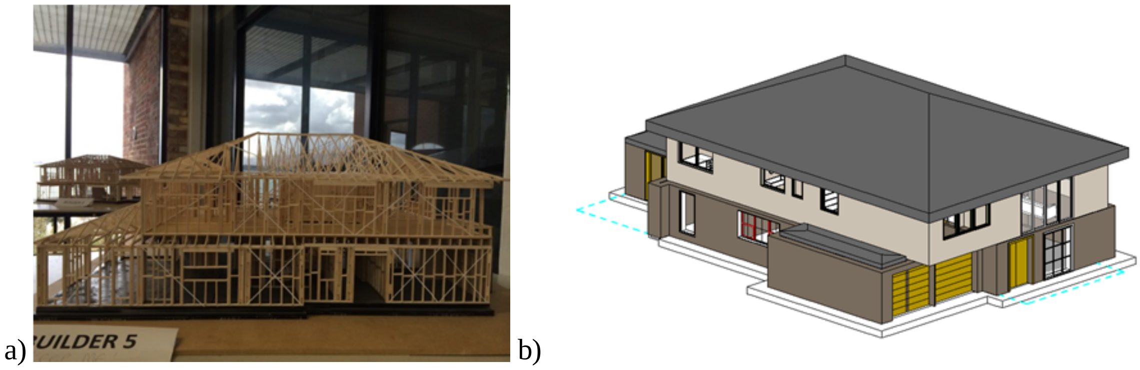

Figure 3. The 3D models of the 'Balmoral-402' building (a) physical (b) virtual

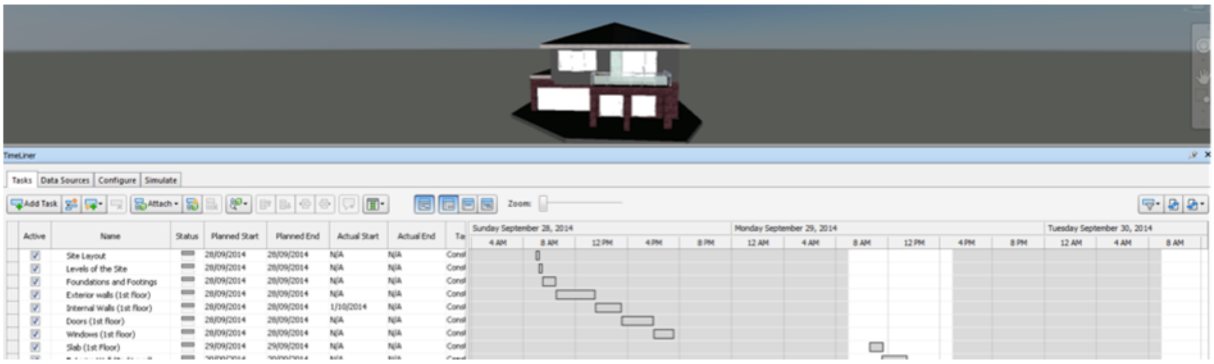

Figure 4. 4D model of the 'Balmoral-402' building

In both units, the students involved in developing building models played the roles of the AEC industry professionals. In the SRT259 unit, teams of sixteen (16) students (builder consortium consisting of four major sub-contractors) developed six (6) physical models, whereas in the SRM165 unit, teams of five (5) students playing roles of an architect, engineering consultant, project manager, quantity surveyor and head contractor developed ten (10) virtual models.

5 IMPLEMENTATION - LEARNING ENVIRONMENT

The learning environment, teaching input and the basic ICT support in the two units are regarded as comparable. In the LMS, the teams are provided with the same access to private discussion forums and lockers, which provide virtual space for collaboration and a platform for documenting team activities and progressive production. The starting point, teaching instructions, specifications and the 2D documentation for creating the physical and virtual models are the same. Also, the generic processes of a model creation such as the analysis of the 2D documentation, conversion of architectural documentation into the 'construction management' documentation as well as documenting the outputs (models, reports and presentations) are the same.

However, the physical model building in the SRT259 unit is additionally supported by an expertise and time of a practicing builder and a workshop staff, who are advising and supervising students in the workshop. Whereas, the teams creating the virtual models are not provided with additional assistance, they are directed to a freely available, web-based resources offered by the BIM technology vendors such as the Autodesk, and also provided an access to the University web-conferencing facilities (BbC - Blackboard Collaborate) in the LMS to further opportunities for virtual collaboration.

Both units require the teams to present models and prepare a technical report on the processes of model development and information defining the models.

6 EVALUATION – LEARNING PRODUCTIVITY

The learning productivity in the case of an ordinary or the BIM-embedded unit are measured by (1) the evidence of learning (output) and/or (2) evidence of learning processes leading to such output. In comparing the learning productivity in these two units the assumption is made that the inputs measured by the effort of teaching staff and students are comparable. Also, the outputs consisting of models, reports and presentations are also comparable. Value of the output in this evaluation is measured by (1) the quantity, (2) quality and (3) the reusability of information (and assumed knowledge) content of any of the models (output). The evaluation was further simplified by the assumption that the presentations and final reports are comparable in terms of the content and its usability for other than assessment purposes.

The learning progresses and progressive learning outcomes related to the models were self-documented by the teams using the LMS's functionalities such as the BbC-videoconferencing, discussion forums and the lockers. In addition, the students could use other ICT tools and media such as widely accessible social media, email exchanges, etc., which are outside the University provided LMS.

The utilization of the LMS by the 94 students (24 teams) who produced physical models was very minimal in comparison with the teams producing the virtual models. On average, the physical modeler (see Figure 5a) produced and stored reusable information in the 0.15 of a document and the 0.07MB of data to be accessible to other team members during the production processes of the physical models. Only five (5) out of the 24 groups stored documents in their group locker. The documents were mainly associated with the initiation of the building model project.

The utilization of the LMS by the 51 students (10 teams) developing the virtual models was drastically different, despite the same level of encouragements by the teaching staff. It needs to be noticed that documenting of processes and progressive outcomes was not part of the assessment in the two units. The virtual modelers, on average produced the 2.6 documents and the 4.4MB of information that were stored in the group lockers and available at any time and any place to other team members during the process of the development of virtual models. Figure 5b presents partially developed BIM model showing the intelligent information of one of the model's elements, in this case, the stairs. The information of all elements of this partially developed model are already integrated and contained in one virtual environment.

a) b)

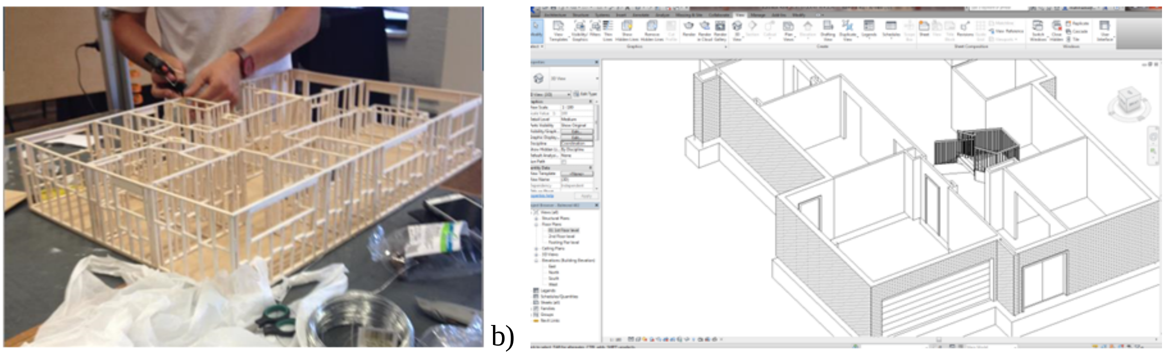

Figure 5. Intelligent information agents (a) physical and (b) virtual modelers

In regards to the final products; the physical and virtual models, the evaluation of evidence of learning is based on the quantity, quality and the reusability of information and consequently assumed tacit and explicit knowledge learnt and communicated via the evidence of learning.

The models are defined and detailed within the models themselves and any supplementary documentation. On average, a physical model and its supplementary documentation contain the 5MB of information data communicated via (.pdf) documents. The evaluation of the quality of this information, the level of its integration, the details and lack of errors is extremely time consuming and difficult to measure. The assessment of reusability of a physical model and its supplementary documentation are limited to the physical presence of a model and the modelers.

A typical virtual model and any supplementary documentation contain the 13.5MB of information communicated via suitable assortment of media/data formats including .pdf, .ifc, .rvt, .nwc, .nwf, .csv, .xlsx, .mpp. All information about any element of the model, including architectural properties, engineering properties, suppliers, cost, environmental performance is contained in the model and modeling environment. The quality of information contained in the virtual models can be easily assessed within the model, eradicating the need to resort to any supplementary documentation (information sources). The 3D virtual models can also be integrated with the proposed construction methods and construction schedule forming the 4D models (see Figure 4), which adds to the informational/knowledge value of the model. The reusability and the scope to manipulate or improve the model is only limited by the access to a standard ICT.

7 CONCLUSIONS

This paper provides ample evidence of learning effectiveness of the BIM centered educational methodology applied to the training of construction projects management professionals. Two comparable learning processes; the BIM and non-BIM supported, as well as their impacts on the effectiveness of learning are presented in this paper. The extreme collaboration and extensive use of the ICT necessitated by the BIM methodology result in learning processes and learning outcomes that outshine conventional educational approaches. The demonstration of learning in the non-BIM supported unit indicates significantly lower quantity, quality and reusability of information and presumably the tacit and explicit knowledge learners communicated via the evidence.

Whereas, the BIM centered education results in the learning outcomes evidenced by intelligent information, which is explicit and easily displayed in the modeling environment, demonstrating well developed knowledge of the architectural and engineering aspects of building designs, as well as the knowledge of construction resources and processes of various building typologies. However, the most valuable products of this type of educational methodology, beyond learning outcomes, are the clearly evidenced collaboration in the creation of knowledge, the co-ownership of the knowledge and the modeling virtual environment, which allows the knowledge be explicit and utilized by anyone involved in creation of this knowledge.

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The authors would like to acknowledge Ms Wai Shuen Kang, who in 2012 undertook an undergraduate research project of high excellence regarding “The future of BIM: reaching its full potential”. Wai concluded in her minor thesis that “to benefit from the full potential of BIM the challenges of interoperability, education, training and reluctance to change by businesses must be addressed”. Wai would be pleased to know that BIM has now embedded itself within the combined Design (Architecture) and Construction Management program.

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