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

BUILDING INFORMATION MODELLING FOR TERTIARY CONSTRUCTION EDUCATION IN HONG KONG

SUBMITTED: September 2010
REVISED: January 2011.
PUBLISHED: February 2011 at http://www.itcon.org/2010/27
EDITOR: Turk Ž.

Kam-din Andy Wong, Dr., Associate Professor,
Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong;
email: bskdwong@polyu.edu.hk

Kwan-wah Francis Wong, Professor,
Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong;
email: bskwwong@polyu.edu.hk

Abid Nadeem, Dr., Postdoctoral Fellow,
Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong;
email: ceabid@polyu.edu.hk

SUMMARY: *Building Information Modelling (BIM) is a thriving technology and approach for the Architecture, Engineering and Construction (AEC) Industry which facilitates, among others, the functions of planning, design, construction and operation of the project lifecycle. BIM is gradually replacing the 2D or 3D CAD technology in many parts of the world. BIM offers wider range of applications than CAD. Therefore, its learning needs are different from the learning needs of CAD. Educators around the world are contemplating with various approaches and methodologies for teaching BIM to tertiary students of the AEC disciplines enabling them to apply BIM in their future careers. These approaches are reviewed in this paper along with the initiatives being taken by the Department of Building and Real Estate (BRE) of the Hong Kong Polytechnic University (PolyU) to incorporate BIM in the construction management, building technology and quantity surveying curricula. Feedback as obtained from questionnaire surveys of students who learned BIM at BRE is analyzed and presented which highlights the knowledge they gained by learning and practicing BIM. Such an approach can be used at universities in other regions and countries and can serve as a guideline for BIM implementations.*

KEYWORDS: *building information modelling, education, architecture, engineering, construction, Hong Kong.*

REFERENCE: *Kam-din Andy Wong, Kwan-wah Francis Wong, Abid Nadeem (2011) Building information modelling for tertiary construction education in Hong Kong, Journal of Information Technology in Construction (ITcon), Vol. 16, pg. 467-476, http://www.itcon.org/2011/27*

1. INTRODUCTION

1.1. Building information modelling

Building Information Modelling (BIM) is a thriving technology and its approach can be used in the Architecture, Engineering and Construction (AEC) industry of different countries. BIM is a successor to the computer-aided drafting (CAD) (e.g. AutoCAD) which started in the 1980s. CAD was initially based on two dimensional drawings and lately on 3D views. However, these drawings lacked the interactivity and the change in one view was not automatically reflected in other views. With the advent of BIM, this practice has gradually started changing since the beginning of the 21st century. BIM based architectural software have allowed the automatic updating of views once the change is made in one view by the production of intelligent 3D/4D models. Besides the form (geometry), BIM is also meant for modelling the functions and behaviour of building systems and components (Sacks et al, 2004). It has made BIM, in this respect, a technology which has a clear advantage over the traditional CAD technology. Such advantages have been well highlighted and researched by other researchers (e.g. Birx, 2005, Khandoze, 2005, Sacks and Barak, 2008).

1.2. BIM and AEC Industry

There is a growing focus of current project management (PM) practices in the AEC industry on integrated project delivery (IPD) and large organizations are adopting such tools which facilitate IPD. BIM by its design facilitates IPD (Hardin, 2009) and, therefore, has tremendous growth potential for PM practices in the AEC industry. In Hong Kong, a growing number of AEC organizations are now adopting BIM in their projects (e.g. Wong et al. 2009). The Housing Department of the Hong Kong Government is actively promoting the use of BIM in its projects and encouraging other stakeholder including the education institutes to train building and construction students in BIM to meet future demands. This trend has given rise to an increasing demand for professionals versed in the art and science of BIM.

1.3. BIM and AEC Education

The support needed for BIM expansion comes from more professionals trained in BIM applications. Such a support has generally lacked in recent years (Young et al, 2008). The essential training in this regard is being provided to students in universities or tertiary educational institutes which offer Information and Communication Technology (ICT) courses in the AEC disciplines. The incorporation of BIM in higher education not only would serve the increasing demand for BIM capable professionals but would also produce new opportunities for students in their professional careers in the form of their ability to deal with new occupational challenges with high efficiency achieved by applying BIM. However, grasping new concepts of BIM is also a great challenge. Therefore, a number of approaches have been adopted to introduce BIM in the curricula (e.g. Sacks and Barak 2010, CIFE, 2010, ITC-Euromaster, 2010, Woo, 2007, Denzer and Hedges, 2008, Burr, 2009). The educational institutions generally have the options of adapting their existing curricula to include BIM for this purpose or teach BIM as separate course or both (Sacks and Barak, 2010). Some institutions adopt the integrated approach while others adopt a standalone approach. The option of adopting BIM as an integrated approach is in line with the requirements of the construction industry. The industry seeks to recruit professionals who can apply knowledge to practical situations which can be better served by coaching BIM as an integrated module in a number of courses. This is more likely through courses which introduce new developments in technology or new methods of project delivery to students.

BIM offers applications for a number of stakeholders throughout the lifecycle of a project. However, in education it is normally taught as a design tool and more specifically, architectural design for students to start learning BIM. In the architectural design representation, BIM enforces a migration from two dimensions to three dimensions by creating intelligent, multi-dimensional building models (Reddy, 2007). However, BIM goes beyond simply representing the geometry of a building. BIM views can show and intelligently interpret the types of materials, construction details including scheduling of building elements for assembly. Through this capability, BIM provides an opportunity to various users with different backgrounds to collaboratively work on one BIM model of a building (Thomson and Miner, 2007). While students learn representing the architectural design in BIM, they would however, have an opportunity to learn other capabilities offered by BIM. Therefore, there is a great need for support to academic institutions to ensure adequate research and development of educational programs in this field.

1.4. Objectives and Methodology

This paper presents the current situation of BIM education in a few countries/regions including Hong Kong. By using the implementation of BIM courses at the Hong Kong Polytechnic University (PolyU) as a case study, in order to analyze the feedbacks of students about BIM education. The paper examines the status of BIM in the curricula of higher education programs in the related disciplines at the PolyU. Questionnaire surveys were conducted with students at undergraduate and graduate levels who studied BIM related courses at the Department of Building and Real Estate (BRE). The survey sought to obtain the opinions of the respondents about the strengths, weaknesses and professional opportunities that may arise as a result of learning BIM in tertiary education.

2. STATUS OF BIM EDUCATIONAL COURSES

Educational institutes in many countries have started teaching BIM applications and have set up curricula for the integration of BIM into the existing courses related to the AEC industry. In the USA, a number of educational institutions are introducing BIM in their curricula. For example, Auburn University started offering BIM with a one-week tutorial, which was followed by a one-semester introductory course on BIM (Taylor et al, 2008). The Architecture Department at The New Jersey Institute of Technology is offering BIM for many years in various upper-level classes which were later converted into a full course and BIM is taught as the main tool in a design studio (Autodesk, 2007). In Hong Kong, the inclusion of BIM technology in undergraduate and graduate curricula is gradually taking place. BRE at the PolyU is offering BIM as part of the higher diploma, undergraduate and graduate levels courses for building and real estate students.

There are a few ongoing multidiscipline courses in Australia and in some other countries. A number of modelling courses are being offered at major universities in countries such as the USA (e.g. Stanford), Germany (Munich), Denmark, Finland, and Sweden. Also, there are a few shorter courses in this field. A sampling of selected BIM courses in the Asia Pacific and Scandinavian countries are listed in Table 1 for an overview of the adoption of BIM in construction education representing two regions of the globe. For a list of BIM course in the USA, readers may refer to Table 2 of the paper by Sacks and Barak (2010). It is to be noted that the courses for BIM are more common than the courses for BIM with Industry Foundation Classes (IFC) which facilitates file exchange scenarios between different design domains and software products. A review of BIM educational approaches, applications, challenges and opportunities is provided in the following two sections.

TABLE 1: A Selected List of BIM and IFC Related Courses in Various Countries (Kiviniemi et al, 2008)

University & Country	Course Name and Short Description	Remarks
University of New South Wales, Australia	Computers and Information Technology (Introduction to BIM, Product Modelling & Interoperability)	Year 1 for all students of all disciplines in faculty
	Computer Aided Design (Taught CAD as a component of BIM, extracting 2D drawings from 3D Models)	Year 2 for architecture students
	Design Collaboration using BIM (BIM with IFC, simulation design teams working in collaboration)	Elective course for Final Year students across various disciplines
	Object Based CAD Modelling	Postgraduate course
Queensland University of Technology, Australia	Coverage of BIM and IFS concepts in other Building courses	Various Levels
	Computer Studies (including BIM)	Year 2 students
	Current Construction Issues (interoperability in construction industry)	Year 4 elective subject
Aalborg University, Denmark	Product Modelling and Product Configuration	
	Product Data and Product Models	
Copenhagen University College of Engineering, Denmark	Digital Building Design (Projectweb, BIM, IFC, Lean Construction)	
	Process Planning under Building Construction	
CE Deptt, Tampere University of Technology, Finland	Information models in the Construction Industry	
Civil and Environmental Engg. Deptt., Helsinki University of Technology	Information Technology in Construction	

(HUT), Finland		
Architecture Deptt, HUT, Finland	Information Management for Architect	
Norwegian University of Science and Technology, Norway	Prefabrication of Buildings based on Digital Models (BIM and IFC) Virtual Building (3D models in architectural design)	
Lulea University of Technology, Sweden	Design of Buildings and Infrastructures Virtual Construction, (collaborator ITC Euromaster program)	BIM in planning and design 4D CAD technology and IFC
National University of Singapore, Singapore	Measurement I, Measurement II, BSc (Building), BSc (PM and FM)Measurement (Building Works)	Introduction to IFC

3. BIM EDUCATION APPROACHES

3.1. Student-centred BIM curriculum development

Burr (2009) discussed the effect of the involvement of students in the course development for sustainable building and BIM. A core group of ten students was enrolled for a course in BIM. The group went through a strategic planning process to select textbooks, supplemental readings, lecture materials, application assignments, and tests. Students examined other universities' programs. Input from industry professionals was also essential to create this intensive course which involved the students to discuss with industry professionals at local, national and international levels, through interviews, site visits, emails, and phone calls. Shared online documents were set up for continuous communication among members of the group which created a lot of useful input from the students. The group looked at many different possibilities for text books. They reviewed abstracts of texts on-line, sample book copies, and finally examined books available on the topics within the campus library. It was concluded that student-driven curriculum development may only be suitable for students who demonstrate a marked interest in the subject matter; otherwise the freedom offered by the independent work and less controlled structure may end up limiting rather than fostering ideas. It was recommended that the process of course design and curriculum development can be improved if students who come from within the program and have an interest in the topics being developed are involved. It was observed that class experience in creative course development not only can be successful, but also creates a win-win situation as it enhances both the students and the teacher's acquisition of BIM knowledge.

3.2. BIM integration approach into construction curriculum

Taylor et al (2008) investigated the integration methods of BIM into the construction management curriculum. They specified prerequisite courses to the BIM curriculum for delivering fundamental skills on digital visualization, CAD drafting and 3D modelling. The first method was the self-taught BIM project in which students were given a project to complete by using BIM software with no formal training or hands-on instructions. This approach got a mixed response from the students who felt BIM was simply too complex to learn on their own without proper guidance. The second method was the introduction of a prototype BIM course to construction management classes. The course covered issues which included architectural, structural and MEP modelling, site plan, estimating template, project schedule, project walkthroughs/animations and the rendering for presentation. Similarly BIM was also incorporated into two of the courses related to construction IT and theses related to BIM were also offered. For theses, they considered incorporating BIM into its requirements for the building construction students.

3.3. Collaborative design and construction

Tisdel and Mulva (2007) investigated aspects of BIM software in collaborative study for design and construction and its use as a tool for cooperation among project participants. Working with BIM, each student or group of students was able to see ideas develop in three dimensions right in front of them, which greatly enhanced the level of knowledge disseminated and the speed in which it was absorbed.

4. BIM EDUCATION APPLICATIONS

4.1. Productivity analysis

Gier et al (2006) investigated the use of BIM for teaching productivity analysis. They explored the components, the advantages, and the disadvantages of BIM through observing student use. The reason for studying this application of BIM was that a 3D model can be linked to an actual project schedule, which can enable a student to assign crews to different parts of the building at particular times during its simulated construction. This was investigated through a qualitative evaluation survey of the student teams who worked with BIM to analyze productivity during the pre-construction phase of a new Student Service Building project on a California state university campus. The research team concluded that BIM enabled the user to calculate and analyze productivity during the pre-construction phase. This 'hypothetical' productivity can then be compared to the actual productivity and the user can adjust crews as needed once actual construction begins. They encountered several problems in the implementation of BIM for teaching productivity analysis which included inexperience of the students with BIM software, lack of BIM software-related instruction, steep learning curve needed for BIM software, lack of BIM trained faculty and laboratory assistants, and lack of clarity of the assignment given to the students. Solutions were recommended to overcome these problems which included stating the purpose of the laboratory assignment more clearly, introducing the learning objectives at the beginning of each exercise, defining and limiting the scope of work for the laboratory assignments, breaking the assignments into smaller incremental components, emphasizing the value of the laboratory assignment to the student's education and career development, and asking leading questions that empower and encourage exploration and experimentation. Overall, the study team concluded that many of the problems experienced were related directly to circumstances encountered in the early adoption phase of new technology implementation. These problems can be effectively mitigated by the proposed solutions which included continuous incremental improvements to the laboratory assignment, the model, supporting materials, and further training of faculty and assistants.

4.2. Plan reading skills

Gier (2007) investigated the effect of BIM on learning the plan reading skills of construction management students. He found that BIM had a small, but positive influence on plan reading skills. The author identified a few challenges to construction management students, which must be overcome for better learning of BIM. These challenges include the high frustration level using BIM software, time commitment to become proficient in BIM software, insufficient training for faculty and laboratory assistants and the retention of BIM understanding by the students.

4.3. BIM as a transformative technology

Livingston (2008) examined BIM as a transformative technology and methodology within the architectural curriculum at Montana State University (MSU) School of Architecture, primarily as a tool for a greater understanding of building materials, assemblies and systems as well as for building systems integration and technical documentation. The successes and shortcomings of BIM integration in the technical course at MSU were outlined. The benefits included exploring new ways of illustrating construction details and methods, developing an understanding of the configuration and construction assembly of various building materials, opportunities for greater communication, and mentally creating a vision for the eventual paradigm shift from 2-D documents to full 3-D digitally based construction documents. The shortcomings included the disjunctive relationship between the details created using BIM software and the overall project, the inability of the curriculum to comprehensively teach students to be competent with BIM applications and the lack of significant preparatory courses to accelerate their knowledge of construction and BIM applications.

5. BIM EDUCATIONAL OPPORTUNITIES

Denzer and Hedges (2008) discuss educational opportunities for the paradigm shift from CAD to BIM. They found that BIM enabled students to think about architecture, structure, and mechanical systems in an integrated manner, and to consider issues of materiality and construction at an earlier stage of design. Students using BIM experienced an accelerated design process compared to those using CAD or other 'traditional' methods. Students using BIM often chose to pursue designs that are more complex compared to designs composed exclusively with CAD, such as exploring eccentric (asymmetrical) geometries. BIM allowed for a more robust exploration of design alternatives 'in process', permitting students to simulate the effects of design alternatives in order to make more intelligent and persuasive decisions. The BIM provides a powerful capacity to facilitate new models of collaboration for student teamwork. They have recommended certain steps which can be implemented for creating 'best practices' of the application of BIM in the education. These include developing an appropriate sequence of prerequisite courses for BIM and using other techniques along with BIM, for example, hand sketching, physical modelling, collage, photomontage, orthographic drawing, etc. Students' understanding to the complexity of BIM should be managed by a gradual introduction from simple problems to complex situations. The innovativeness of students should be encouraged in the use of BIM.

6. BIM EDUCATIONAL CHALLENGES

Woo (2007) investigated the challenges that may involve in the introduction of BIM into construction education. These challenges include the level of knowledge required to use BIM software, lack of reference materials, and model development not following the construction sequence, lack of intelligent error detection and correction by the BIM software and limited choices of component databases. Woo further concluded that teaching and learning BIM requires higher level of construction expertise based upon practical experience. Faculty members should place more emphasis on the use of BIM through reconfiguration of current courses to deliver the required working knowledge for BIM. A major issue is how to set up a new course based on the concept of BIM. It might be a challenge for faculty members to fit all course contents into one. Faculty members should deliver working knowledge on BIM software, together with architectural drafting and construction technologies. A rich and rigorous learning environment could be achieved through purposeful attempt of integrating BIM into various course contents such as residential design, commercial design, construction estimating, construction project management or construction scheduling. According to a survey by Kiviniemi et al (2008), traditional parameters like constant software upgrading, costs and education are the main obstacles preventing a higher level of usage of ICT, including BIM.

7. IMPLEMENTATION OF BIM EDUCATION AT THE POLYU

7.1. Current BIM implementation

At BRE of the PolyU, BIM is being gradually incorporated in the curriculum based on the institutional policy for curriculum development named as the Discipline Specific Requirements (DSR) exercise. In consultation with the academic staff, recommendations regarding BIM education have been made by the Departmental Academic Advisor (DAA) in his annual report, which is being followed by BRE in adapting the curriculum in future. According to the recommendations, primarily an integrated approach of BIM education had been adopted which means that aspects of BIM are being gradually introduced to students in several subjects. Besides a standalone BIM subject is also offered as an elective module. Training in the use of Building Information Modelling is provided in Year 1 and its application when teaching subjects such as estimating, scheduling, structures, and mechanical systems in subsequent years. This approach has been deemed suitable as it has aligned BIM with the existing structure of the curriculum. Also, an application based approach rather than architectural design based approach has been chosen for BRE students. Table 2 highlights the application of BIM at the PolyU at various stages of student curricula.

TABLE 2: BIM related courses at BRE in PolyU

Level	Discipline	Year	Subject	Duration
Higher Diploma	Building Technology and Management	1	BRE210 "Information and Data Analysis"	4 weeks
Undergraduate	Building Engineering and Management and Surveying	1	Building Information Modeling	14
		3	BRE439 "Engineering Contract Procedure"	1 week
		3	BRE416 "Computerized Construction Production Management	1 week
MSc	Project Management/ Construction and Real Estate		BRE511 "Construction Information Management"	1 week
			BRE574 "Construction Process Management"	1 week
			BRE586 "Construction Information Technology"	1 week

BIM being taught in BRE is mainly from the builders' and surveyors' point of views, rather than from the architect's point of view, for which it includes the following specific BIM applications.

- Development of CAD in construction.
- General introduction of BIM and the current status.
- BIM use in building design with emphasis to the basic operations of Revit.
- Visualization in design reviewers to incorporate comments and communication.
- BIM use in quantity surveying, cost estimation and materials procurement.
- Clash detections and 4D to nD applications in construction management.
- The application of BIM in property and facility management.
- The future development and potential of BIM in construction.

Some post-model solutions such as Navisworks Manager and Navisworks Freedom are being introduced into the new 4 year curriculum BRE regarding the BIM application in construction management. Ecotect is applied for sustainable design and the assessment of energy saving.

7.2. Proposed BIM Implementations for Future

Considering the current academic research, professional development and industrial market, BIM is being considered highly significant to the future development of construction information technologies and to the construction industry. Feedback was invited from faculty members on the incorporation of BIM in the curriculum. Faculty members recognize the importance of BIM in educating construction professionals in the current decade. The subject "Drawings and CAD" was proposed as a compulsory DSR subject for all students from the Faculty of Construction and Land Use (FCLU) which comprises of four departments including BRE. In consultation with the academic staff of FCLU it was recommended that for the time being an appropriate proportion for the newly proposed subject would be 20% for manual drawing; 50% for CAD and 30% for BIM. With the passage of time, it is anticipated that BIM's proportion would be increased eventually to replace CAD.

Additionally, in line with the recommendations of DAA and the DSR initiative, a course entitled 'Information Technology for the Construction Industry' is being proposed. This course aims to provide students with an introduction to the well-established and also emerging IT solutions being used in the construction industry. BIM is part of the course contents of this subject along with virtual prototyping. Students will learn this subject through lectures, which will be supplemented by tutorials and laboratory works. Laboratory works will be carried out in the Construction Virtual Prototyping Laboratory in BRE to facilitate learning of virtual prototyping and virtual reality. Tutorials will be conducted in different formats to encourage active participation of students, e.g. problem-solving exercise, case studies and student presentations.

In the recent DAA report, it is recommended to promote Integrated Project Delivery (IPD) method and BIM in the curriculum. DAA commented that IPD method was a collaborative approach that allowed data sharing between design and construction team at an early stage in a project to maximize value for the owner. The use of BIM provides far greater information collaboration between project participants and is considered an important tool in implementation of IPD. The industry needs a new generation of architects/construction managers who are competent in application of BIM in transferring information efficiently and decreasing errors made by design/construction teams. For this purpose, a three credit course of the title "Information Technology and Systems (BIM + Virtual Prototyping)" will be offered at the Faculty level (FCLU) in the new four year degree curriculum. This new course will provide opportunities to BRE students to learn about the IPD method and the importance of collaboration between the design and construction teams at an early stage of a project. BRE students will have a rich knowledge of using BIM upon graduation.

8. FEEDBACK OF STUDENTS ON BIM EDUCATION AT POLYU

It is important to get the feedback from students to gauge the effectiveness of BIM education at the PolyU. It was sought in the form of a structured questionnaire survey which was conducted once the students were trained in BIM after 4 hours of theoretical and 6 hours of practical lessons. A total of 78 students participated in the survey. Majority of students (75 nos.) heard about BIM from the class tutor who trained them in BIM software and related theory. A vast majority (73 nos.) of students already know how to use the 2D CAD from AutoCAD whereas Architectural Desktop, which is a software from Autodesk, was used by only 12 students before. Students felt that BIM software Revit from Autodesk was easier to use, convenient, provided better visualization, less dependent on typing commands, provided more information of the components and was easy to draw in 3D. However, for 2D drawings, students felt AutoCAD was easier to use than Revit.

8.1. Benefits of Learning BIM

Respondents commented on the benefits of learning and acquiring BIM skills. More than 60% of the students agreed that they had better understanding on building structure after learning BIM. More than 45% of the students agreed that BIM knowledge was also useful for other building and construction related subjects. Half of the students considered that BIM enhanced their confidence in applying for competitive positions in the job market. There was no clear majority in the opinion of the students about the usefulness of BIM for non-building or non-construction (such as Civil Infrastructure, Interior Design) related subjects, as 40% of the students agreed while about half of the students had a neutral view. This may be because of the limited knowledge of students about areas other than their subject of study.

8.2. Improvement of BIM Teaching

This survey also asked about improving BIM teaching in the future. Results showed that more than half of the students agreed to learn more in-depth BIM in both theory and hands-on practice. Fifty six percent of the students intended to have more hands-on experience in using BIM software and 53% of the students looked for further training in Autodesk Revit. Only a few students (14%) did not intend to get further training of BIM as a subject and less than 10% of the students disagreed to have BIM software training again.

8.3. Comments on BIM Software Training

More than half of the students gave a positive appraisal to the BIM training using Revit Software. Forty percent of the students were neutral on BIM's positive appraisal. A few students (less than 10%) were not satisfied with BIM's training sessions. Students provided a few comments about their assessment of BIM training. One of the students got bored. A few students needed more clear explanations from the instructor during the lessons. A few students looked for how to build more structural components on a building.

9. CONCLUSIONS

This paper has provided a review of BIM in tertiary education in the AEC disciplines. A number of universities around the world are offering courses for various applications of BIM. Such courses are often accompanied by IFC Industry Foundation Classes (IFC) which facilitates file exchange scenarios between different design domains and software products. Three BIM education approaches were discussed which include student centred curriculum, integration approach into curriculum and study of collaborative design. Some BIM education applications were also presented which included the productivity analysis, plan reading skills and transformative role of BIM. It was discovered that the incorporation of BIM in education had certain challenges which include the level of knowledge required to use BIM software, lack of reference materials, and model development not following the construction sequence, lack of intelligent error detection and correction by the BIM software and limited choices of component databases. However, it was also found that the incorporation of BIM enabled students to learn design process quickly as compared to those using CAD or other 'traditional' methods. It also enabled students to understand and create complex designs such as eccentric geometries which were not easy to comprehend using only CAD technology.

Secondly, the current and proposed implementations of BIM education at the PolyU are presented. It shows that BIM is being gradually and systematically introduced at the PolyU to cater for the requirements from the AEC industry and facilitating integrated project delivery systems which is supported by the literature review presented in the introduction section and review of BIM education approaches and applications. The implementation of BIM education presented may be useful in universities at other places as well. Feedback from the students showed positive results towards the BIM training in terms of its perceived benefits and further improvement of BIM teaching.

10. ACKNOWLEDGMENT

The authors gratefully acknowledge the funding support provided by The Hong Kong Polytechnic University (Project account 1-ZVOA).

11. REFERENCES

Autodesk (2007). *Revit BIM Experience Award: New Jersey Institute of Technology* , Available at: http://tinyurl.com/njitbim

Birx G.W. (2005). BIM evokes revolutionary changes to architecture practice at Ayers/Saint/Gross, *AIArchitect*, The American Institute of Architects, Vol. 12, 09 December.

Burr K.L. (2009). Creative course design: a study in student-centered course development for a sustainable building/BIM class, *Proceedings of the 45th Annual Conference by Associated Schools of Construction,*(Sulbaran T. and Sterling C., editors), University of Florida, Gainesville, Florida, USA. Apr 1-4, Available at: http://ascpro0.ascweb.org/archives/2009/CERT82002009.pdf

CIFE (Center of Integrated Facilities Engineering) (2010). *VDC Certificate Program*, Available at: http://tinyurl.com/cifevdc

Denzer A.S. and Hedges K.E. (2008). From CAD to BIM: educational strategies for the coming paradigm shift, *Proceedings of the 2008 Architectural Engineering National Conference* (Ettouney M., editor), The Architectural Engineering Institute (AEI) of the ASCE, September 24-27, Denver, Colorado, USA, Available at: http://dx.doi.org/10.1061/41002(328)6

Gier D.M. (2007). Does learning building information modeling improve the plan reading skills of construction management students? *Proceedings of the 43rd Annual Conference by Associated Schools of Construction*, (Sulbaran T. and Cummings G., editors), Northern Arizona University, Flagstaff, Arizona, USA Apr 12 – 14, Available at: http://ascpro0.ascweb.org/archives/2007/CEUE146002007.pdf

Gier D.M., Loftin E. and Coogan K. (2006). Are building information models effective for teaching productivity analysis? *Proceedings of the 42nd Annual Conference by Associated Schools of Construction*, (Sulbaran

T., Brana M., Silva A. and Corage S., editors), Colorado State University, Fort Collins, Colorado, USA, Apr 20 - 22. Available at: http://ascpro0.ascweb.org/archives/2006/CEUE02_Gier06_300.htm

Hardin B. (2009). *BIM and Construction Management: Proven Tools, Methods, and Workflows*, Indianapolis, Indiana, USA. Wiley Publishers.

ITC-Euromaster (2010). *European Master in Construction Information Technology,* Available at: http://tinyurl.com/itceuro

Khanzode A., Fischer M. and Reed D. (2005). Case study of the implementation of the lean project delivery system (LPDS) using virtual building technologies on a large healthcare project, *Proceedings of the 13th Conference of the International Group for Lean Construction*, (Kenley R., editor), Univesity of New South Wales, Sydney, Australia, 153–160.

Kiviniemi A., Tarandi V., Karlshøj, J. Bell, H. and Karud, O.J. (2008). *Review of the Development and Implementation of IFC Compatible BIM*, Available at http://www.eracobuild.eu/fileadmin/documents/Erabuild_BIM_Final_Report_January_2008.pdf

Livingston C. (2008). From CAD to BIM: constructing opportunities in architectural education, *Proceedings of the 2008 Architectural Engineering National Conference* (Ettouney M., editor), The Architectural Engineering Institute (AEI) of the ASCE, September 24-27, Denver, Colorado. Available at: http://dx.doi.org/10.1061/41002(328)5

Reddy K.P. (2007). How BIM is speeding up the greening of healthcare design, *Healthcare Design,* November, Available at: http://tinyurl.com/reddykp.

Sacks R., Eastman C.M. and Lee G. (2004). Parametric 3D modeling in building construction with examples from precast concrete, *Automation in Construction*. Vol. 13, No. 3, 291–312.

Sacks R. and Barak R. (2008) Impact of three-dimensional parametric modeling of buildings on productivity in structural engineering practice, *Automation in Construction*, Vol. 17, No. 4, 439–449.

Sacks R. and Barak R. (2010). Teaching building information modeling as an integral part of freshman year civil engineering education, *Journal of Professional Issues in Engineering Education and Practice*, ASCE, Vol. 136, No. 1, pp. 30-38.

Taylor J.M., Liu J. and Hein M.F. (2008). Integration of building Information modeling (BIM) into an ACCE accredited construction management curriculum, *Proceedings of the 44th Annual Conference by Associated Schools of Construction*, (Sulbaran T. and Sterling C., editors) Auburn University, Auburn, Alabama, USA, Available at: http://ascpro0.ascweb.org/archives/2008/CEUE246002008.pdf

Tisdel R.C. and Mulva S. (2007). A case study of a design-build competition in a construction program, *Proceedings of the 43rd Annual Conference by Associated Schools of Construction*, (Sulbaran T. and Cummings G., editors), Northern Arizona University, Flagstaff, Arizona, USA Apr 12 – 14, Available at: http://ascpro0.ascweb.org/archives/2007/CEUE168002007.pdf

Thomson D. and Miner R. (2007). BIM contractual risks change with technology. *Construction Executive*, 60-64. Available at: http://www.constructionexec.com/Files/9.07Issue.pdf

Wong A.K.D., Wong F.K.W. and Nadeem A. (2009). Attributes of building information modelling and its development in Hong Kong, *The HKIE Transactions*, Vol. 16, No. 2, 38-45.

Woo J.H. (2007). BIM (Building Information Modeling) and Pedagogical Challenges", *Proceedings of the 43rd Annual Conference by Associated Schools of Construction*, (Sulbaran T. and Cummings G., editors), Northern Arizona University, April 12 - 14, 2007. Available at: http://ascpro0.ascweb.org/archives/cd/2007/paper/CEUE169002007.pdf

Young N.W., Jones S.A. and Bernstein, H.M. (2008). *SmartMarket report on Building Information Modeling (BIM): Transforming Design and Construction to Achieve Greater Industry Productivity*, McGraw-Hill, New York. USA.