Virtual Plan-Design-Build for Capstone Projects in the School of Architecture: CM & BIM Studios in Five-Year B.Arch. Program

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Abstract

Diversification in project delivery methods (PDM) over the last two decades has significantly changed the roles of architects, engineers, and contractors in the construction industry. Under the emerging alternative PDMs, the common requirements for architects include 'planning capability', 'integrated understanding of design and construction', and 'IT skills' in addition to traditional architects' qualifications. In order to meet these requirements, a novel approach to educating future architects was attempted at Myongji University as a capstone project for the 5-year architecture program. This studio was entitled CM & BIM studio focusing on three objectives in design studios; planning, life-cycle integration, and building information modeling (BIM). This paper proposes a curriculum for the CM & BIM studio with detailed teaching objectives and student deliverables. Educational requirements in the age of new architecture were identified first. The CM & BIM studio in 2012 as a case study was introduced in order to validate the adaptability of proposed curriculum. Comments from professors and architects verified and encouraged the promising educational results intended in this paper. Finally, findings and lessons learned are also briefly discussed.

Keywords: B.Arch. program; capstone design studio; CM; BIM; planning

1. Introduction

Recent changes in project delivery methods (PDM) has actively utilized alternative methods including design-build (DB), CM at risk (CMR), design–build–maintain (DBM), and integrated project delivery (IPD). Fundamental differences of alternative PDMs as opposed to traditional methods may include 'contract awarding based on technical competence rather than price', 'pursuing best values in terms of cost, time, quality throughout the project life-cycle', and 'promoting maximum interactions among participants in order to achieve effectiveness'.

Under these emerging alternative PDMs, the role of architects needs to be significantly expanded further to have 'planning capability', 'integrated understanding of design and construction', and 'IT skills' in addition to traditional architects' qualifications.

In this context, the purpose of this paper is to propose a methodology for the capstone studio to educate young architects during their five-year school of architecture programs.

2. Educational Requirements for Capstone Studio

Great Schools Partnership (GSP 2014) defines a capstone project as "a multi-faceted assignment that serves as a culminating academic and intellectual experience for students, typically at the end of an academic program or learning-pathway experience".

Traditional capstone projects in the school of architecture have mainly focused on architectural 'design for the design phase' of a project. However, as discussed previously, competent architects have to be actively involved in the planning phase as well as the construction phase in order to better communicate with owners, contractors, and all other participants.

As a means of communication and collaboration, the capability of utilizing information technology (IT) is also crucial for contemporary architects. Therefore, the knowledge and skills relating to construction project management (CM) and building information modeling (BIM) can be important aspects of the capstone design studio in the school of architecture.

2.1 CM and BIM Capability for Architects

One of the basic principles of CM is performing managerial functions from the owner's perspective encompassing the entire project life-cycle. Namely,
the traditional architects' scope of work should be further expanded into planning and coordinating many different construction functions among many different project participants.

Capabilities of being competent architects in terms of CM functions include preparing 'feasibility study', 'project execution plan (PEP)', 'request for proposals (RFP)' and 'project control plans in the planning phase'. The feasibility study, PEP and RFP for design and construction defines prime objectives and concepts for basic design as well as the entire project. However, preparing and writing these documents requires practical skills and it has been hardly addressed in architecture capstone studios. By its nature, the capstone design studio is the ideal course for students to learn these CM capabilities because students can exercise CM functions by using their own design plans.

As for BIM, more public and private owners demand mandatory use of BIM (Khemlani 2012). Efforts are also made to improve the competitiveness of the construction industry by enhancing BIM knowledge and skills (Pikas et al. 2013). Accordingly, universities have recognized the need for BIM education, and a growing number of schools have added BIM to the architecture curriculum. However, there is a concern that universities end up simply teaching BIM software skills as the BIM education method has not yet been fully developed (Barison and Santos 2010). Consequently, the lack of students' BIM expertise has become an industry-wide issue. Furthermore, without professional and continued training, it is hard to expect overall growth of BIM utilization with high expertise (Sacks and Barak 2009).

2.2 Capstone Studios in Universities

In order to identify course requirements for integrated capstone projects (CM & BIM studio in this study), seven schools introduced in international journal papers were reviewed and analyzed. As presented in Table 1., six different variables are defined in this paper to compare the seven schools. The six variables include 'program' in terms of academic major, 'course type', 'collaboration type', 'project life-cycle' addressed in studio, 'BIM function' and 'emphases' of each studio. Seven schools have recognized well the needs for CM and BIM education, and offered outstanding curriculums in different ways.

The first variable of 'program' (column 'A' in Table 1.) defines the academic major. The seven cases consist of two architecture (ARCH) majors, two civil engineering (CE), two construction management (CM), and one architectural engineering (ARE) program. The second variable (column 'B') indicates the 'course type' and whether it is a regular course or a capstone project. Four cases teach CM and BIM in a capstone project while three cases are taught in a lecture format with hands-on experiments. The third variable of 'collaboration type' (column 'C') characterizes the method of collaboration. Five cases try to utilize interdisciplinary integration between many different courses within their schools (e.g., building methods, materials, structural analysis). It is interesting that Case 3 attempts to simulate web-based collaboration among different project participants by using a commercial data management software for BIM workflows. Case 6 utilized a secured file transfer protocol (ftp) website in order to facilitate distance collaboration of conceptual design work between students in two different schools (Hedges et al. 2008).

While the first three variables (column A, B, and C in Table 1.) are based on each school's academic program and course, the last three variables represent CM and BIM features. The variables of 'project life-cycle' and 'BIM functions' are composed into several constituents. 'Project life-cycle' has six phases as shown in Table 1. Ten areas of 'BIM functions' have been selected based on frequently discussed issues in BIM education literature (Becerik-Gerber et al. 2011; Sacks and Pikas 2013).

Observations based on the aforementioned variables found that the prime objective of Case 1 is to enhance students' understanding of the latest IT and tools, namely, perceiving the impact of new technology on construction management (CM) functions. In addition, by using a cyber-learning platform, students form a team to learn collaboration through virtual projects (http://cee.usc.edu). As for Case 3, an 'online 3D construction model' is utilized as a tool that enables efficient information management and collaboration by dividing the students into groups for role playing for the purpose of systematic exchange of project information (Hu 2007). These cases commonly emphasize effective collaboration between project participants. However, developing students' own design documents were not implemented as these courses are in the form of a regular lecture.

Capstone projects have better benefits in this sense because a student has his or her own model that can be used for BIM or CM exercises. Case 4 is a capstone project in a Civil Engineering (CE) program. Though it does not actively utilize BIM, practicing RFP, the LEED check list emphasizes the students' understanding of CM among different project participants mainly in the design phase (Barry et al. 2010).

The last three cases are capstone design studios in architecture (ARCH) or architectural engineering (ARE) programs. The capstone studio in Case 5 made efforts to help students understand the collaboration among many different participants throughout the design and construction phases, where BIM was also actively used (Parfitt et al. 2013). In contrast, Case 6 focuses on BIM skills in order for students to learn how to develop 3D drawings and how to comprehend design concepts in a broader sense by using BIM tools and expertise (Berwald 2008). Finally, and interestingly, Case 7 puts an emphasis on the use of
BIM for construction project management functions including estimating, scheduling, and quantity take-off (Azhar et al. 2010). It is found that the six variables with sub-constituents, identified in this paper for evaluating the integrated design studios, effectively characterize different cases.

The literature review in Table 1. summarizes overall course descriptions based on the six variables defined in this paper. As each program has different course objectives, every case has its strength. However, it was found that none of the previous programs tried to comprehensively integrate CM and BIM techniques within a capstone project, especially addressing a
wide spectrum of practical applications. None of them introduced detailed teaching methods and student output in a structured manner.

3. Integrated Capstone Studios (CM & BIM)

An integrated attempt was made in Case 8 (this study) to comprehend the whole project life-cycle as well as many different BIM features in a single capstone design studio for five-year architecture programs. A capstone course entitled CM & BIM studio was taught at Myongji University in 2009, 2010, and 2012. As depicted in Tables 1. and 2., the CM & BIM studio in this paper focuses on the 'planning capability', 'integrated understanding of design and construction', and 'IT/BIM skills' in addition to traditional capstone studios.

3.1 Objectives of the CM and BIM Studio

Course objectives were set based on four major requirements. The first one is to meet international accreditation criteria. As listed in Table 2., specialization of the program or studio (O11), integrated with many disciplines (O12), and design within the urban context (O13) were chosen at the case-university.

The second requirement focuses on the CM basics, including integration (O21), planning (O21), and coordination (O23) capabilities. The following one deals with BIM skills; BIM authoring for geometry (O31), non-geometry (O32), and also the capability of using BIM-based analyzing tools (O33). Finally, the requirement in terms of practical skills (O40) was defined in three areas including industry issues (O41), project execution (O42), and IT utilization (O43).

3.2 Methods to Meet the Requirements

Experimental learning methods to meet the studio objectives are briefly summarized in the last column of Table 2. Learning methods, listed in Table 3., are composed of five major areas including writing project plans (D02 in Table 3.), preparing contract documents (D03), developing design documents (D04) and construction documents (D05), and utilizing BIM tools (D06).

By developing a feasibility study (D02) for the students' own project, they can experience the issues of integration (O21 as studio objectives in Table 2.) between design, construction, and operation phases along with industry issues in practice (O41). Preparing a detailed 'project execution plan' (D0202) enables the student to have capabilities for planning (O22) and project execution (O42). Developing contract documents (D03), construction drawings (D0404), and structural analysis (D0405) helps to enhance the capabilities for CM integration (O21) and 'integrated design with other disciplines' (O12).

In the same manner, studio objectives listed in Table 2. were addressed by using the learning methods listed in Table 3.

This comprehensive scope and massive output requires tremendous time and effort. It was possible because the CM & BIM Studio was a semester course (ten hours per week for five credit hours) where five to six students worked together as a team. Each student was in charge of the role of owner, architect, engineer, contractor, or CM. Real-world examples of feasibility study, project execution plans, and standard contract forms were provided to the students for reference, so they could start writing their own documents. Lectures for economic feasibility were also held in the studio.

However, major tasks were exercised individually in order to experience practical tasks. Especially, for the architectural design, each student was required to develop his/her own plan as an alternative. Then the student in the role of the architect chose the best plan following extensive discussions. Benefits from role-playing include the students' understanding of complex interactions and coordination, different participants' responsibilities, as well as collaboration skills through active meetings and discussions. Details of the learning methods and students' deliverables are listed in Table 3.

4. Case-Study: CM & BIM Capstone Studio

The CM & BIM studio in this study follows the sequence of project life-cycle as shown in Table 3., which describes the studio's assignments and consequential deliverables from students.

Fig.1. was the final presentation of the students' deliverables in the capstone exhibition for graduation. High-resolution images of the panels can be found at www.cicms.org/CM-BIM-Studio/ or www.cicms.org/bbs/board.php?bo_table=StudentWork Fig.2. shows some specific parts of the capstone panels (in Fig.1.), which are selected to explain further in this paper.

4.1 Step 1: Planning

First step in the proposed curriculum starts with setting up project plans ('D00_Project Theme', 'D01_Project Outlines', 'D02_Project Plans' in Table 3.). Summary of these plans are documented by writing a feasibility study report (D0201) and a project execution plan (D0202).

The CM & BIM Studio held in 2012 developed a large complex facility consisting of 'waterfront park', 'premium outlet', and 'desalination plant' together, of which the preliminary budget was about 270 million US dollars with a duration of 48 months for design and construction, as summarized in Table 3. and shown in the dotted Box 'A' in Fig.2.

Comprehensive studies for project objective settings, market analysis, and economic feasibility analysis were performed by the students. As summarized in Table 3., one of the objectives of this project was to harmonize a desalination plant within this architectural complex to enhance the architectural value of public plants. This project also aims to boost tourism in the Incheon international airport vicinity where the project site is located.
Site selection was quantitatively evaluated using four major criteria; desalination plant requirements, demography, accessibility, and land price. The analytical hierarchy process (AHP) developed by Saaty (1982) was used as the evaluation method.

The result of the economic feasibility study by students showed that it has an 8.83% rate of return (ROR) over a 34-year life-cycle time period. In order to conduct this economic analysis, students calculated preliminary estimates for three facilities included in their project. Microsoft Excel was used to calculate the discounted cash-flow diagram. A special interest rate offered by the government was also considered for the 'desalination plant' as it was a public facility.

Because students in the architecture program do not have enough understanding regarding the desalination plant, they visited a construction company several times in order to learn the overall concepts and structures. Thanks to the practitioners' help, they were able to understand the basic processes and costs required to build the plant. This type of supplementary education is an important consideration for architects in complex projects. Dotted block 'D' in Fig.2. represents the process and floor plan of the desalination plant.

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**Table 3. Course Deliverables from CM & BIM Studio at Myongji University**

| Studio assignment | Students' deliverables (Studio held in 2012) |
|-------------------|---------------------------------------------|
| D00_Project theme | "Blue Factory on the Waterfront" (Waterfront + Premium outlet + Desalination plant) |
|                   | Located in Incheon City, - 71,600 m² of total building area |
| D01_Project outline | - 48 months for project duration, - 270 million US dollars of project budget |
| D02_Project plans | - 'Harmonization of desalination plant within waterfront architecture' |
|                   | - 'Boosting tourist and commercial development in Incheon Airport vicinity' |
|                   | - Project objective setting, Market analysis, Technical feasibility (plant, buildings) |
| D0201_Feasibility study | - Economic feasibility (34 years, ROR 8.83%, sensitivity analysis performed) |
|                   | - Site evaluation and selection (plant requirement, demography, accessibility, price) |
| D0202_Project execution plan (PEP) | - Selection of PDM (Master architect MA 1, CM for fee CM 1, Design-builder DB 3) |
|                   | - Owner's work breakdown structure formulation (based on 3 projects) |
|                   | - Integrated schedule and budget (engineering/procurement/construction/O & M) |
|                   | - Other execution plans from the owner's perspective |
| D03_PDM & Contracts | - CM (1) + MA (1) + Bridging DB (3) to enhance effectiveness and performance |
| D0301_RFP | - Request for proposal (RFP) for bidding |
| D0302_CM contracts | - CM contract (throughout project life-cycle, based on AIA standards, in English) |
| D0303_DB contracts | - Architectural DB for outlet, Plant DB for desalination, Civil DB for waterfront |
|                   | - Three DBs coordinated by MA and CM |
| D04_Design/Engineering | - Integrating waterfront, plant & outlet to improve cultural and tourist environment |
| D0401_Conceptual | - Integrated program for project objectives (circulation flow, outlet location, park) |
|                   | - Plant capacity (desalination 130,000 m³/day), Equipment list with specifications |
| D0402_Preliminary | - Space program for plant based on 'equipment capacity' and 'process flow' |
|                   | - Space program for outlet based on merchandiser (MD) plan: |
|                   | - Site 130,000 m², Gross floor area 71,600 m², Building area 43,400 m² |
| D0403_Basic design | - Building-to-land ratio 33%, Floor space index 55% |
| D0404_Detailed design | - Construction drawings for outlet unit, Shop drawings for steel structure, Others |
| D0405_Structural | - Focused on steel structure for entire projects, BIM-based structural analysis |
|                   | - Automated cost estimating for steel structure based on the BIM model |
| D05_Construction | - Construction plans by zones for the mega-project |
| D0501_Budget | - Total budget including architecture, plant, and waterfront |
|                   | - Details for plant equipment, steel structure, curtain wall, and outlet unit module |
| D0502_Schedule | - Integrated CPM schedule comprehending architecture, plant and waterfront |
|                   | - Including plan/design/procurement/construction as well as based on cash flow |
| D0503_Reports | - Progress reports with cost and schedule, countermeasure and forecast included |
|                   | - Earned value management system (EVMS) used |
| D06_BIM | - 3D-CAD design documents, connected with non-graphic data (4D, nD-CAD) |
| D0601_BIM objects | - Site layout, Plant layout, Outlet unit module, Steel structure details |
| D0602_BIM methods | - Quantity take-off, Estimating |
| D0603_BIM analysis | - Visualized scheduling (4D-CAD), Structural analysis |
developed by the students.

After analyzing the feasibility (D0201, a 42 page-long report), students then developed the project execution plan (PEP, D0202) to select the project delivery method (e.g., three packages of design-build in Table 3.), to develop a physical breakdown structure (PBS) for this project, and to define other managerial methods as an owner. For the space program, a list of required square footage for each room or space was also quantified based on this feasibility study. Examples of the PEP were provided by the professor, and students then developed their own by customizing.

As a result of PEP (D0202), it was decided to have five different contractors including one construction manager (CM), one master architect (MA), and three design-builders (for park, premium outlet, and plant facilities). One student took charge of the role of owner, and five other students worked as the CM, MA, and three DBs, respectively.

4.2 Step 2: Contract Documents

As a second step, students wrote a request for proposals (RFP, D0301) in order to solicit the CM firm, master architect (MA) and three design-builders (DBs). Real-world RFPs were searched and downloaded from the Internet for reference. Students also used the Korean standard forms as well as AIA contract document forms to elaborate their project’s specifics into standard contract documents (D0302).

Experiencing project delivery methods (PDMs) and real-world contract clauses for their own project facilitated the students to clearly understand roles and responsibilities among different project participants.

4.3 Step 3: Design

The next step is to develop design documents including conceptual design (D0401), preliminary design (D0402), basic design (D0403), details for major parts (D0404), and structural analysis (D0405). The different outputs for each design stage are summarized in Table 3.

A space program developed in the planning phase was used to develop floor plans. As for the structural design, the entire steel structure was analyzed by using 3D-based commercial software (Midas) as shown in dotted box 'E' in Fig.2.

Faculty members specialized in architectural design as well as structural analysis joined for part of this studio to assist these processes. It is encouraging to have a team-teaching environment, as the students can receive advice from different perspectives.

4.4 Step 4: Construction

The fourth step is to perform quantity take-off (QTO) in order to develop a construction budget (D0501) and planned schedule (D0502). A monthly report of cost and schedule was also written (D0503) at a midpoint of the construction phase. These tasks culminated their undergraduate studies in an effective manner.

The preliminary budget and schedule as part of the feasibility study (D0201) were used as a base for developing detailed construction cost and schedule. Detailed estimating was focused on plant equipment, steel structure, curtain wall, and unit module of an outlet. Examples are shown in Box ‘C’ & ‘E’ in Fig.2.

4.5 Step 5: BIM

Finally, many design documents and construction reports (D06) were generated by using BIM functions (column ‘E’ in Table 1.) such as 3D authoring, quantity-taking-off, model-based estimating, 4D-scheduling, and 3D structural analyses. Some snapshots from BIM & CM studio 2012 are introduced in Fig.2.

Information technology (IT) skills taught within this studio include 3D-CAD (Revit), CPM scheduling software (MS Project), spreadsheet (MS Excel), relational database management systems (MS Access), and structural analysis software (Midas).

Excel and Access were used to manipulate estimating and cost reports. These IT skills were integrated with 3D-objects in order to understand and implement BIM. For architectural design, two-dimensional (2D) and three-dimensional (3D) CAD systems were complementarily used together (AutoCAD & Revit). Due to the huge project size, it was not easy to fully use 3D-CAD for all components. 'Steel structure' and 'unit module for outlet' were fully explored in terms of details and practicability by using 3D. Students also surveyed current market prices of land, equipment, materials, labor, and services for the entire project. This is another benefit for students in understanding real-world practices from a comprehensive perspective. It was emphasized that ‘total amount’ and ‘total duration’ should be thoroughly and systematically estimated even though there exist different levels of detail for different disciplines or components. By doing it this way, students can understand concrete concepts regarding the entire scope and characteristics of their project.

4. Conclusions

The ever-changing environment of the architecture/engineering/construction (AEC) industry requires changes in architects’ capability. In order to educate this capability, a comprehensive curriculum was developed for capstone projects in the 5-year Bachelor of Architecture (B.Arch.) programs. The CM & BIM studio in this paper has provided education concerning professional skills for IT applications and CM techniques throughout a ‘cyber design-build project’ within a design studio.

Findings during the three-year operation of the proposed CM & BIM studios at Myongji University reveal that architecture students easily perceive the CM and BIM concepts due to their planning capability training throughout the undergraduate design studios. This capability could prepare students to work for owner organizations as well as architectural firms and general contractors. It was also found that role-playing contributed significantly to this.
It is important that the students perform hands-on exercises of practical issues by using CM and BIM techniques. The CM & BIM studios facilitated the students' understanding thanks to the usage of their own design for relevant documentation and analyses.

Perhaps one of the best examples is the 'pre-project planning' as an owner. Students developed a feasibility report that contained market analyses, site selection, and rate of return (ROR) analysis for entire life-cycle costs. This report was used as a crucial base for
preliminary design with a detailed space program. Another benefit of this integrated studio was to begin design tasks with the construction and maintenance in mind.

The final presentations of CM & BIM studios at Myongji University underwent official critiques by invited professors and architects. Their comments proved that the studios were successful enough in terms of educational requirements and practical capabilities.

The authors hope that this paper will be a reference for an integrated capstone studio at other schools. The students’ activities and assignments introduced in Table 3. could be a starting point for formulating studios. The different objectives and characteristics of each school will be important considerations in differentiating studios.

It was possible to perform all activities listed in Table 2., thanks to the team of six students working together. However, each student was evaluated individually by his/her own contribution and assignments.

Even though approximate costs for all disciplines and components were included in the total project cost, this studio could not perform the mechanical, electrical, and plumbing (MEP) drawings and energy analyses, which will be considered for future studios. 3D-CAD based applications for MEP and energy analyses would enhance this studio significantly.

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References
1) Azhar, S., Sattineni, A., and Hein, M. (2010) BIM undergraduate capstone thesis: Student perceptions and lessons learned. Proceedings of the 46th ASC Annual Conference, Boston, MA.
2) Barison, M. B., and Santos, E. T. (2010) BIM teaching strategies: an overview of current approaches. Proc., ICCBEE 2010 International Conference on Computing in Civil and Building Engineering
3) Barry, B. E., Drnevich, V. P., Irfanoglu, A., and Bullock, D. (2010) Summary of developments in the civil engineering capstone course at Purdue University. Journal of Professional Issues in Engineering Education & Practice, 138(1), pp.95-98.
4) Becerik-Gerber, B., Gerber, D. J., and Ku, K. (2011) The pace of technological innovation in architecture, engineering, and construction education: integrating recent trends into the curricula. Journal of Information Technology in Construction, 16, pp.411-432.
5) Berwald, S. (2008) From CAD to BIM: The experience of architectural education with building information modeling. Proceedings of AEI 2008 Conference, Building Integration Solutions, ASCE, pp.1-5.
6) GSP (Great Schools Partnership). (2014) The glossary of education reform for journalists, parents, and community members. July 2014 http://www.greatschoolspartnership.org.
7) Hedges, K. E., Denzer, A. S., Livingston, C., and Hoistad, M. (2008). Socially responsible collaborative models for green building design. Proc., AIA Research for Practice Program Grant.
8) Hu, W. (2007) Implementing a simultaneous construction model to educate undergraduates in collaboration. Proceedings of Annual Conference of the ASEE.
9) Khemlani, L. (2012) Around the world with BIM. AECbytes feature.
10) Parfitt, M. K., Holland, R. J., and Solnosky, R. L. (2013) Results of a pilot multidisciplinary BIM-enhanced integrated project delivery capstone engineering design course in architectural engineering. Proceedings of AEI 2013 Conference, Building Solutions for Architectural Engineering. pp.44-53.
11) Pikas, E., Sacks, R., and Hazzan, O. (2013) Building information modeling education for construction engineering and management. II: Procedures and implementation case study. Journal of Construction Engineering and Management, 139(11).
12) Saaty, T. L. (1982). Decision Making for Leaders, Life Time Learning Publications, Belmont, California, USA.
13) Sacks, R., and Barak, R. (2009) Teaching building information modeling as an integral part of freshman year civil engineering education. Journal of Professional Issues in Engineering Education and Practice, 136(1), pp.30-38.
14) Sacks, R., and Pikas, E. (2013) Building information modeling education for construction engineering and management: Industry requirements, state of the art, and gap analysis. Journal of construction engineering management, 139(11).
15) USC (University of Southern California). (2014) Homepage of USC, May, 2014, http://cee.usc.edu