

Probing BIM Education in Construction Engineering and Management Programs Using Industry Perceptions

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The construction industry is actively adopting Building Information Modeling (BIM) technology and Virtual Design and Construction (VDC) practices to benefit from improved collaboration through the capability of visual communication. From the literature, it appears that BIM technology and VDC practices also improve student learning and the effectiveness of teaching, thereby increasing students' active engagement. To foster this industry innovation, Construction Engineering and Management (CEM) programs need to think how best to offer considerable opportunities for teaching BIM and VDC to students, integrating with traditional or mainstream courses. Students with the relevant BIM knowledge and skills will have a competitive edge in the current job market. The objectives of this study were to investigate current BIM trends and practices in the construction industry and to propose an approach to leverage BIM in construction education. For this study, we performed an extensive literature review, reviewed syllabi for BIM-related courses currently offered by CEM programs, and analyzed survey responses from eleven industry experts involved in BIM or VDC. This paper reports our findings of the current BIM trends and practices in the construction industry and the current status of BIM education in CEM programs. In addition, we share recommendations for leveraging BIM into construction education.

Key Words: Building Information Modeling; BIM Education; Curriculum Development; Undergraduate Education

Introduction

The use of Building Information Modeling (BIM) has grown within the construction industry over the last five years. BIM has been increasingly adopted to improve the construction process, thereby saving time and money, and reducing the number of requests for information (RFI) and field coordination problems. According to a 2009 McGraw-Hill Construction publication, devoted to this subject, nearly 50% of the industry is using BIM, its adoption will increase, and positive returns from the use of BIM or BIM-related tools is expected (Young et al., 2009). Perhaps, the most important value of using BIM or BIM-related tools is the facilitation of effective communication and collaboration among project participants, thereby providing a competitive advantage within the construction industry.

This momentum has been shared by professional and industry organizations including the American Institute of Architects (AIA), the Associated General Contractors (AGC), and the American Institute of Steel Construction (AISC), as well as public sector bodies such as the U.S. General Service Administration (GSA). Many of these organizations have issued BIM guides and appropriate contract forms, such as the Consensus DCCS 301 BIM Addendum and the GSA BIM guide (Young et al., 2009). Even though BIM is becoming widely adopted in the construction industry, the lack of individuals with BIM skills and knowledge is a key issue in effectively utilizing BIM (Hartmann & Fischer, 2008; Gu & London, 2010; Wong et al., 2011).

Adequate BIM training is essential to advancing the construction industry into the BIM age. In parallel with industry, CEM programs need to integrate BIM within their curricula ensuring that students enter the workforce with the requisite BIM knowledge and skills they will need in their future careers. Therefore, both industry and academia need to focus on BIM training and education to maximize the values and benefits from the use of BIM.
Leading construction companies have created new BIM and VDC positions to make the transition from current practice to the one that integrates BIM technology into their organization. Individuals in these new positions are responsible for implementing BIM on their projects while balancing their traditional operational duties. Generally,

training in BIM and VDC has occurred internally within a construction company. CEM programs can play a vital role in BIM education and training thereby lowering the internal training burden of construction companies. Without a doubt, the demand for more individuals with experience and knowledge of BIM technology and VDC practices exists. Several CEM programs offer BIM courses or modules to their students. Nevertheless, BIM education within CEM programs is still in the early adoption stage. Becerik-Geber et al. (2011) investigated the level of BIM integration into the current construction related curricula. They identified that most CEM programs had recently started offering BIM courses. However, their investigation revealed that 57% of engineering programs and 36% of construction management programs had yet to develop undergraduate level BIM courses. According to this study, "Only slightly over half of all programs offer BIM courses and almost one fifth of all programs still do not have any plans to offer BIM courses" (Becerik-Geber et al., 2011).

Becoming skilled in using BIM technology cannot be gained through one or two intensive courses alone. In most cases, those courses fall short of the expectation of BIM fluency. Moreover, BIM training within a CEM curriculum usually focuses on usage of the technical software tool, not on the VDC processes inherent with BIM implementation. CEM programs need to develop and implement best practices in teaching BIM and VDC to students, thereby fostering further industry innovation as graduates enter the workforce.

Research Objectives and Methodology

The objectives of this study were to investigate current BIM trends and practices in the construction industry and to propose an approach to leveraging BIM within construction education. To pursue these objectives, we generated the following four research questions about BIM and its potential impacts on construction education:

1. What is the current status of BIM education within the CEM undergraduate curriculum?
2. To what extent should students be exposed to BIM in order to reflect industry's current BIM usage?
3. What level of BIM skills and knowledge does industry expect from recent graduates?
4. What would be the best approach to incorporating BIM into the CEM curriculum?

We first performed an extensive literature review followed by a study of current syllabi for BIM-related courses offered by CEM programs. This task enabled us to understand the current status of BIM education in the CEM undergraduate curriculum. Secondly, we conducted a survey of twenty industry experts in BIM or VDC. Survey responses captured industry's current BIM trends and practices, and identified industry's expectations for BIM skills and knowledge of recent graduates. Additionally, the authors' corresponded personally with other BIM colleagues and developed insights on BIM implementation issues and practical BIM integration. These collaborative efforts were undertaken to effectively leverage BIM into construction education.

BIM Education in CEM Programs

We explored and analyzed the BIM-related courses currently offered by CEM programs. We conducted a web search of CEM programs' undergraduate course catalogs to identify BIM-related courses. Syllabi for eleven BIM-related courses were identified and obtained from the course's website or through request made to the instructor. These eleven syllabi were reviewed in detail. Appendix A presents the course titles and course objectives extracted from our syllabi review. Appendix A entries are ordered alphabetically by the course title. Major topics covered in the BIM-related courses included:

- Interdisciplinary team collaboration
- 3D visualization and communication with building information
- Constructability review and clash detection between structural and MEP systems
- Quantity takeoffs

Simultaneously with the syllabi review, we conducted an extensive review of relevant literature to identify the different pedagogical methods used and the lessons learned when BIM is incorporated into construction education. We restricted our literature review to recent manuscripts published by ASEE, ASCE, and ASC during 2007 through

2011. During these past five years, CEM educators have summarized the benefits of BIM in construction education through several published articles; eighteen of which are referenced in our literature review.

Our review identified four implementation strategies that have been employed to incorporate BIM topics into the CEM curriculum:

- Stand-alone course at the lower level (often replacing an existing CAD class with a BIM class)
- Interactive teaching modules integrated into numerous upper level courses
- Cross-curriculum teaching modules between different disciplines
- BIM capstone course or project

We compiled our summary of the literature first by the implementation strategy employed, followed by identifying the curriculums known to have employed that strategy, we then identified the authors who reported on the implementation, and finally, presented the key outcomes and/or limitations encountered. This summary is presented in Table 1.

Table 1. Summary of BIM Implementation Efforts in CEM Undergraduate Curricula

Strategy Employed for BIM Implementation	***Course***	***Reference***	***Learning Outcomes and Technological Limitations***
Stand-Alone Course	Residential and Commercial Design	Woo (2007)	• Better understanding of 1) design, construction, and engineering information and 2) the architect's role in the design and construction process • Limitations in using BIM software in creating various models
	Engineering Elective	Dupuis et al. (2008)	
	Architectural Engineering Graphics	Weber & Hedges (2008)	
	Digital Construction Graphics	Taylor et al. (2008)	
Integrated Teaching Modules	Construction Documents	Livingston (2008)	• Enhanced student's ability to understand 1) building structures & components; 2) complex construction systems; 3) construction plans & specifications; and 4) construction means & methods • Improved accuracy of student's quantity takeoffs • Positive perceived impact on students' learning and student's willingness to use BIM • Effective course content delivery for the active learning
	Building Envelopes	Dong (2009)	
	Residential Construction	Meadati & Irizarry (2010)	
	Structural Design	Barham et al. (2011)	
	Materials & Methods	Glick et al. (2011)	
	Engineering Graphics	Sacks & Barak (2010)	
	Formwork	Meadati et al. (2011)	
	Mechanical and Electrical	Korman & Simonian (2010)	
	Scheduling	Hyatt (2011)	
	Estimating	Sylvester & Dietrich	
Cross-Curriculum Teaching Modules	Construction Management and Structural Engineering Courses	Richards & Clevenger (2011)	• Better understanding of 1) roles and responsibilities of other disciplines; 2) the complexity and variety of information between different disciplines; and 3) collaborative work environment for the construction process
	Integrated Studio	Sharag-Eldin & Nawari (2010)	
	Architectural Design Studio	Hedges & Denzer (2008)	
Capstone Project	Capstone Course	Azhar et al. (2010)	• Students' strong interest in learning BIM • Difficulty in using BIM tools for a capstone project

Many of the cases presented in Table 1 were "pilot projects" where BIM was deployed in a course for the first time and the impacts on student learning evaluated. These efforts within the CEM curriculum show great potential for successful BIM implementation in an undergraduate curriculum.

BIM Trends and Practices within the Construction Industry

We surveyed industry experts to understand the current practices and trends related to BIM use in construction and to identify industry's expectations for BIM skills and knowledge of recent graduates.

First, we piloted our survey methodology during December 9, 2011 to January 12, 2012. Nine individuals from three different companies participated in this pilot study. Respondents provided comments on the clarity and format of the survey instrument. We subsequently revised the survey instrument to improve the quantification of data gathered. The improved survey was distributed via email to twenty industry BIM experts. We selected the BIM experts to receive the survey based on the following criteria that established our targeted profile requirements:

- Be members of construction firms using BIM technology for construction projects in the United States.
- Have at least 5 years of experience in the construction industry.
- Belong to the Virtual Design and Construction department within their own company.
- Have job titles directly related to BIM operations (examples: BIM director, BIM manager, Virtual Construction Manager, etc.).

Out of the 20 experts contacted, eleven individuals from nine different companies responded. The overall response rate was 55%. Survey responses were collected from February 16, 2012 to March 9, 2012. All the companies represented in the survey responses mainly focused on commercial building projects.

Each respondent was asked to answer a series of questions. The survey was divided into three main categories. The first category included "Respondent Information" and "Company Information" to confirm that the participant met the target profile requirements. The second category consisted of "BIM Implementation" and "BIM Training" inquiries to gather general information about the current practices and trends for BIM implementation and training. The third category focused on capturing the respondents' professional opinions on BIM topics for construction education and their current perception of "BIM Education in CEM programs." Due to paper length restrictions, we focus our subsequent discussion on the data obtained from responses within the third category.

Survey Results and Data Analysis

The data analysis of our survey results was vital to obtain quantitative information that can be used to establish the foundations of BIM education in CEM programs, as well as corroborating the findings from our review of literature and BIM-related course syllabi. To facilitate the analysis of the survey data, this section has been divided into three subsections.

BIM Implementation in Construction

BIM has been gaining substantial momentum in the construction industry over the last five years. However, BIM implementation is still at the early adoption stage in the construction industry. The survey identified that only 36.4% of the respondents have been using BIM for over 5 years. Companies most frequently reported having 4 to5 years of implementation experience (45.4%) while 18.2% noted only 2 to 3 years usage. The survey data also indicated that 90.9% of the respondents are using BIM for more than 40% of on-going construction projects. Based on this analysis, BIM usage is an increasing trend on construction projects.

BIM Training in Construction

All companies that responded had internal, experienced BIM trainers to deliver company training; 90.9% have a structured BIM training program within the company. This trend was expected since use of internal BIM operators to deliver training yields more benefits to the company in terms of their specific BIM strategies and business needs.

We then sought to quantify what the respondents perceived as the important topics within BIM training and what their needs are to support BIM implementation. Perceptions were quantified by using a response scale ranging from

1 (not at all important) to 5 (very important) for a listing of BIM-related training topics. The results are shown in Figure 1 through a box-plot display. Responses confirmed that internal BIM training emphasized basic BIM software skills, clash detection modeling, and 3D modeling for detailed conditions. More variation in responses was evident with regard to 4D training, and design, structural, and MEP analysis training.

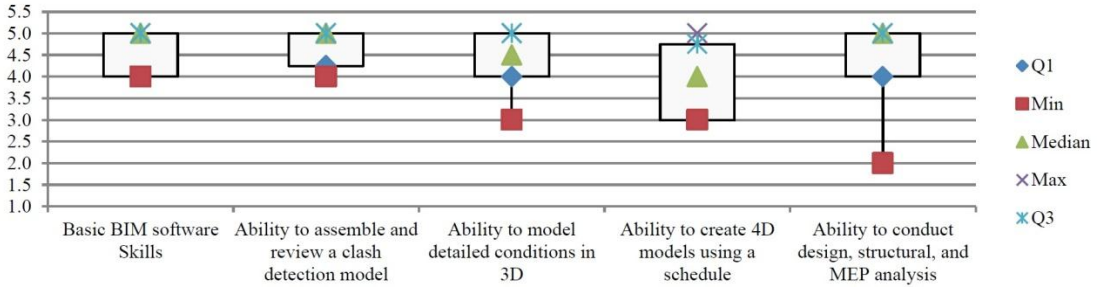

Figure 1: BIM Training Subjects in Construction Firms

One of the respondents noted, "Our training program is just in time training for field team members on the project site, provided by our integrated construction coordinators. Our focus is on how to leverage the tools that apply to daily activities. We don't train how to model, but how to use the model to help daily activities."

BIM Education in CEM Programs

Incorporating BIM usage into the CEM curriculum is desirable because it enables graduates to remain competitive in the job market and translates into potential training cost savings for employing companies. A respondent noted that they anticipate a change in their workforce in a few years to incorporate BIM/VDC processes. Construction firms are looking for new hires with broad experience in BIM, but the supply of this type of individual is very limited. Therefore, the CEM curriculum must be reorganized or restructured for industry's BIM education needs. Figure 2 depicts the major BIM topics desired within the undergraduate curriculum, as identified from our survey. The main topics desired for BIM education in a CEM curriculum are clash detection, spatial trade coordination, and site logistics – all unanimously rated as "highly important" by industry experts. Comparison of the relative importance of all nine BIM education topics is presented in Figure 2 through box-plots.

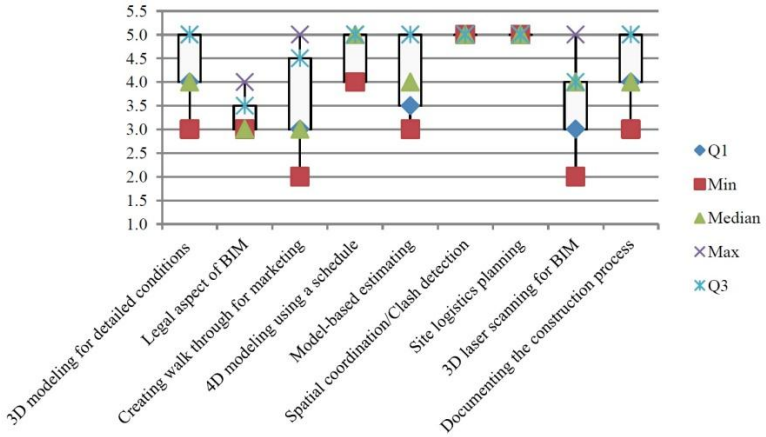

Figure 2: Major Topics for BIM Education in a CEM Curriculum

Additionally, the respondents suggested other topics related to concepts and trends using BIM and recommended these topics be covered within the CEM curriculum:

- Current BIM implementation areas in construction

- Process change from BIM use
- BIM as an underlying enabler of effective team communication
- Integration of design and construction models, target value design, and facilities management
- Leveraging the efficiencies of BIM into the construction process

The industry BIM experts anticipate that students who graduate from CEM programs should be knowledgeable of BIM concepts and evolution, trades and systems that frequently partake in the BIM process, BIM model management to facilitate the BIM process, and BIM standards and interoperability issues. In addition, students should understand the roles and responsibilities of the participants within the BIM process through some experience of interdisciplinary team collaboration.

Discussions and Conclusion

Industry's adoption of BIM has gained significant momentum in a relatively short period of time. There will be an enormous demand for individuals who have the requisite BIM skills and knowledge for entry-level employment in the construction industry. As the industry's realization of the values and benefits from using BIM continues to grow, it is apparent that BIM education should be integrated into the CEM curriculum more broadly. CEM programs need to move quickly to adopt BIM in their curriculum in order to address the industry's need for graduates with BIM education. The construction industry expects CEM graduates to be fully aware of what BIM is and understand its potential benefits, even though they may not have been exposed to its full application within their studies.

The focus of BIM education within CEM programs should be on BIM trends and processes, not on BIM software such as Revit, AutoCAD, or Google SketchUp. Teaching students how to create 3D models of building systems in a virtual world is not a true BIM education. Just knowing how to create 3D building models within a software program does not necessarily mean one can capitalize on the value of BIM. Users need to know how to extract needed information from 3D and/or nD BIM models, and then collaboratively share that information to support construction processes.

There are a wide variety of processes and steps for virtual construction use cases. Having standards in collaboration with the industry may be essential, particularly when incorporating BIM into CEM curriculum. A survey respondent noted, "We are moving to a time when most major subcontractors are creating models for their work. Being able to manage the information from multiple parties and extract what is important is critical." Therefore, CEM curriculum should stay afloat for industry advancements and trends. In addition, faculty members who teach BIM-incorporated courses should stay in touch regularly with the industry to reconfigure the course contents reflecting the industry trends and practices.

CEM programs need to offer BIM learning opportunities to help students derive insights about future BIM functions. The most practical approach to BIM education would be the integration of BIM into mainstream CEM courses. A rich and collaborative learning environment is possible through purposeful integration of BIM into various courses. This integrated format for construction education will also provide students with a higher quality of education. The essential key to implementing a BIM integration plan, however, will be clear administrative support and commitment to ensure success.

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Appendix A

BIM-related Courses Offered by CEM Programs

Course Name (Institution)	***Course Objectives***
Advanced Topics in CAD & BIM (University of Massachusetts Amherst)	Knowledge of advanced topics in architectural CAD software and its uses in design and construction; The ability to work in 3-dimensional modeling and create 3D models of construction assemblies and buildings; The ability to create a parametric building model and extract data; The ability to use CAD-based tools to solve technical issues during the planning process; Understanding of industry common BIM software such as Revit, Navisworks, Google SketchUp and AutoCAD
BIM (Stanford University)	Creation, management, and application of BIM; Process and tool for creating 2D and 3D computer representations of building components and geometries; Organizing and operating on models to produce architectural views and construction documents, renderings and animations, and interface with analysis tools
BIM (Southeast Missouri State University)	Understand concepts of Building Information Modeling (BIM); Review software and technology available for BIM; Use BIM software to create a model of a building; Use BIM to check for interferences and conflicts on a building construction project; Explore construction scheduling and sequencing using BIM; Explore cost estimating using BIM; Explore how BIM can assist in Facilities Management
BIM (Southern Polytechnic State University)	Develop the knowledge and skills required for generating and modifying BIM using Revit Architecture, Revit Structure, and Revit MEP; Perform quantity takeoffs and cost estimates; Identify the constructability problems using BIM
BIM (University of Arkansas)	Basic functions of BIM for residential and commercial construction; Understanding of geometry, spatial relationships, geographic information, quantities and properties of building components; Creation of virtual models of buildings that can be used for quantity takeoffs
BIM for Commercial Construction (Purdue University)	Understanding of BIM use for commercial construction; Understanding of geometry, spatial relationships, geographic information, quantities and properties of building components
Building Information Modeling and Integrated Practices (University of Southern California)	Understanding of the shift from representation to simulation; Familiarity with the current BIM technologies; Understanding of new means of coordination and collaboration of design and construction; Understanding of the linking and maintaining continuity of existing and designed BIM information and other vital information into the model; Understanding of new project delivery systems and technologies for 'integrated practice'; Outlook to how innovative technologies could be integrated into the current AEC practices
CAD & BIM for Construction Managers (Oklahoma State University)	Interpretation and production of construction drawings using computer aided drafting; Theory and use of Building Information Modeling software
Construction Documentation and BIM Applications in Engineering and Construction (University of Maryland)	Understanding of construction documentation methods; The ability to read and coordinate construction drawings prepared by various project consultants; The knowledge to manage and implement BIM technologies in the design and construction processes
Industry Applications of Virtual Design & Construction (Stanford University)	Investigate in the management of Virtual Design and Construction (VDC) programs and projects in the building industry; Interacting with experts and professionals in real estate, architecture, engineering, construction and technology providers to learn from the industry applications of BIM and its relationship with Integrated Project Delivery, Sustainable Design and Construction; Evaluate the maturity of VDC planning, adoption, technology and performance in practice
Virtual Construction (University of Washington)	Proficiency in the processes of program and project management, applications of BIM, documentation, and quality control; Competency in 3D visualization, site planning, clash detection, and 4D modeling; Understanding of web-based project management systems, BIM tools, construction contracts, and design and construction procedures; Awareness of designers' and contractors' rights